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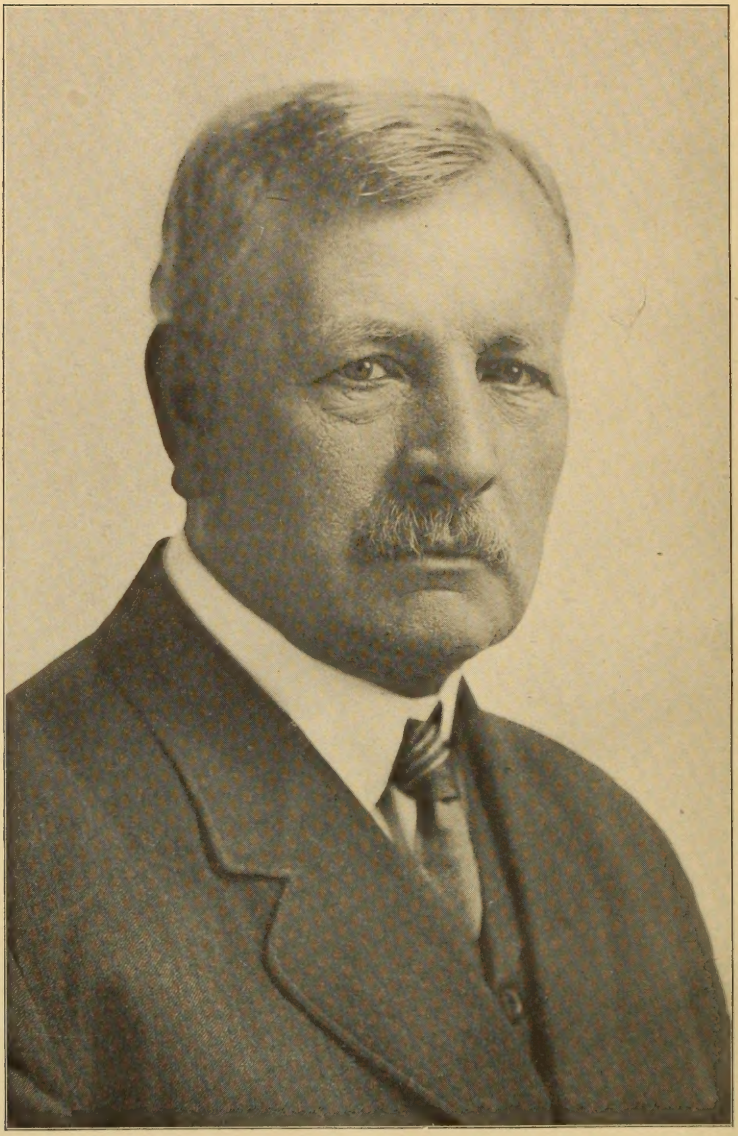

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PROCEEDINGS

OF THE

THIRTY-THIRD ANNUAL CONVENTION

OF THE

AMERICAN WATER WORKS ASSOCIATION

HELD AT

MINNEAPOLIS, MINNESOTA, JUNE 23-27, 1913

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The Association is not responsible, as a body, for the facts and opinions advanced in any of the papers or discussions published in its Proceedings

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CONSTITUTION OF THE AMERICAN WATER WORKS ASSOCIATION

ARTICLE I

Name

The name of this Association, a corporation organized under the laws of the State of Illinois, shall be "The American Water Works Association."

ARTICLE II

Object

The object of this Association shall be the advancement of knowledge of the design, construction, operation and management of water works, and the encouragement, by social intercourse among its members, of a friendly exchange of information and experience.

ARTICLE III

Membership

Section 1. Members of this Association may be either Honorary Members, Active Members, Corporate Members, or Associate Members.

Section 2. An Honorary Member shall be one whose scientific or practical knowledge in matters related to public water supply, or whose accomplishments in that field of endeavor, shall entitle him to especial recognition by the Association. Honorary Members shall have the same privileges as Active Members, but shall not be required to make any payments for the support of the Association.

Section 3. An Active Member shall be either a Superintendent, Manager or other officer of a municipal or private water works; a civil, mechanical, hydraulic or sanitary engineer, a chemist or bacteriologist; or he shall be otherwise qualified for and actually engaged in the advancement of knowledge relating to public water supply.

Section 4. A Corporate Member shall be either a Water Board or Commission, or a Water Company, and shall be entitled to one representative who shall have all the rights and privileges of an Active Member.

Section 5. An Associate Member shall be either a person, firm

or corporation, engaged in manufacturing or furnishing materials or supplies for the construction or maintenance of water works. An Associate Membership shall entitle the holder to be represented by one person on the floor at each meeting but such representative shall not be entitled to vote or take part in any discussion unless permission is given by unanimous consent of the members present; provided, however, that Associate Members may vote on selection of the place of meeting as provided in Article 9, Section 1, each Associate membership being entitled to one vote only.

Section 6. When an Active Member so changes his vocation that were he to apply for membership he would be classed as an Associate Member, he shall be classed as an Associate Member, but no further initiation fee shall be required.

ARTICLE IV

Admission and Expulsion

Section 1. The Executive Committee may, at its discretion, at the request of any member, present the name of any person qualified for Honorary Membership, to the Association for election to that grade of membership; but the Executive Committee must, upon the written request of twenty-five members, so present the name of any such person to the Association.

Section 2. Any person, firm, corporation or water department desiring to become an Active, Corporate, or Associate Member must make application for the grade of membership sought, upon the blank form provided by the Association. Each application must be endorsed by two members of the Association, shall embody a concise statement of the applicant's qualifications for membership and be accompanied by the initiation fees and dues as hereinafter provided. All applications must be forwarded to the Secretary who shall submit them to the Membership Committee, as soon as possible.

A unanimous affirmative vote of the Membership Committee shall elect to Active, Corporate or Associate Membership.

Section 3. No member whose dues are in arrears shall receive the publications of the Association until such dues are paid. Members in arrears for one year shall be dropped from the roll by the Secretary.

Section 4. Any member who has been suspended for non-pay-

ment of dues may be reinstated by the Membership Committee upon payment of all back dues. He shall then be entitled to receive such back numbers of the publications of the Association as may have been withheld from him on account of non-payment of dues, and are not out of print.

SECTION 5. Any member of any grade may be expelled from the Association for cause, upon the recommendation of the Membership Committee, adopted by a two-thirds vote of the members present and voting at any annual convention.

SECTION 6. Any member may retire from Membership by giving written notice to that effect to the Secretary, provided that he pay all dues to that date, unless released from said payment by the Executive Committee.

ARTICLE V

FEES AND DUES

SECTION 1. Each Active Member shall pay an initiation fee of Five Dollars, and annual dues of Five Dollars.

SECTION 2. Each Corporate Member shall pay an initiation fee of Ten Dollars, and annual dues of Five Dollars.

SECTION 3. Each Associate Member shall pay an initiation fee of Ten Dollars, and annual dues of Ten Dollars.

SECTION 4. The fiscal year of the Association shall begin April 1st and terminate on March 31st. Annual dues shall be payable in advance and shall be due on April 1st, the first day of the fiscal year covered by said dues. It shall be the duty of the Secretary to notify each member on or before March 15th of the amount due from said member for the ensuing year.

SECTION 5. Any newly elected member shall be entitled to all the publications of the Association that are distributed to its members during the year. Members elected later than December 1st shall not be required to pay the annual dues for the current year, but if they do pay said annual dues they shall receive all the publications to which members in good standing are entitled for that year.

SECTION 6. In case any application for membership shall be rejected the initiation fee and dues which accompanied the application shall be returned to the applicant.

SECTION 7. Any Active Member in good standing in any Interstate, State or Local Association formed for the same general pur-

pose as this Association, and which has been approved as such by the Executive Committee of this Association, who may apply for Active or Corporate Membership, may be admitted by the Membership Committee without the payment of the regular initiation fee; provided he shall furnish evidence that he has paid, during his membership in such Interstate, State or Local Association, in fees and dues, an amount equal to or exceeding the initiation fee required in this Association and is at the time of making application for membership in this Association, an Active Member in good standing in said Interstate, State or Local Association.

ARTICLE VI

Officers

Section 1. The Officers of the Association shall be a President, one Vice-president, Treasurer, Secretary, and Editor of the Association's publications. The offices of the Secretary and Editor may be combined at the discretion of the Executive Committee.

Section 2. There shall be an Executive Committee in whom the government of the Association shall be vested. It shall consist of the President, Vice-president, Treasurer, Secretary, Editor, the Chairman of the Finance Committee, the last two living past presidents and six trustees. No two trustees shall be residents of the same state. The President and the Secretary of the Association shall be the President and the Secretary of the Executive Committee.

Section 3. At least sixty days before each annual meeting of the Association, the Secretary shall mail to each Active, Honorary, or Corporate Member a blank upon which the member may express his choice for President, Treasurer and two Trustees. The Secretary, in conjunction with two other members to be designated by the President, shall count all nominating ballots received by the Secretary not later than thirty days before the date of the annual meeting.

The four members who shall have received the greatest number of nominating ballots for the office of President, the three members receiving the greatest number for Treasurer and the six members who shall have received the greatest number for trustees shall thereby be placed in nomination. If there be a tie vote among the number required to be placed in nomination, an additional number of names to cover such ties shall be placed in nomination.

Tickets shall be printed on which the names of nominees shall be placed in the order of preference, the name of the person receiving the greatest number of nominating ballots for each office to be placed at the top of the list of nominees for that office.

SECTION 4. The election shall be by letter ballot. At least twenty-one days before the date of the annual meeting, a ticket shall be mailed to each member of the Association entitled to vote. Each member shall be entitled to vote for one candidate for President, one candidate for Treasurer and two candidates for Trustees.

The ballot shall be sealed separately in a special ballot envelope. This ballot envelope shall be enclosed in a larger envelope and forwarded to the Secretary. The signature of the member voting shall appear on the outer envelope.

The Secretary with two canvassers appointed by the President shall meet at a time and place directed by the President, and shall open and count all ballots cast by persons entitled to vote. No ballot shall be counted if received later than seven days previous to the beginning of the annual meeting.

The result of the canvass for President, Treasurer and Trustees shall be declared by the President at the annual meeting on certification of the canvassing board.

The member who shall have received the plurality of the votes cast for the office of President shall be declared elected. The member receiving the next highest number of votes for President shall be declared Vice-president. The member who shall have received the highest number of votes for Treasurer shall be declared elected. Subject to the provision that no two trustees shall be residents of the same State, the two members who shall have received the greatest number of votes for Trustees shall be declared elected.

If there be a tie vote the President shall order a vote to be taken in the annual meeting to decide which person of those who shall have received the same number of ballots shall be chosen.

The terms of the officers so elected shall be as follows: For the President, Vice-president and Treasurer, each one year beginning with the close of the last day of the annual meeting and ending the last day of the next annual meeting, or until his successor shall have been chosen; for the Trustees, three years beginning with the close of the last day of the annual meeting.

SECTION 5. The Secretary and Editor shall be elected by the Executive Committee at the time of the annual meeting, the outgoing Executive Committee electing said officers for one year

beginning with the close of the last day of the annual meeting or until their successors are chosen.

SECTION 6. In case of the absence, death or inability of the President to perform the duties of his office, his position shall be temporarily filled by the Vice-president, and in case of the absence, death or inability of the Vice-president, his position shall be filled by one of the Trustees; the order of precedence being governed by the date of election as Trustee or the dates of the election being the same, by the date of admission of such Trustee to membership in the Association.

SECTION 7. All vacancies in office except as provided in Section 6 hereof shall be filled by vote of the Executive Committee for the unexpired term of said office as soon as practicable after said vacancy occurs.

SECTION 8. The President and Trustees shall be ineligible to election for a consecutive term.

ARTICLE VII

DUTIES OF OFFICERS

SECTION 1. The President shall have general supervision of the affairs of the Association, and shall preside at all meetings of the Association and of the Executive Committee at which he may be present.

SECTION 2. The Executive Committee shall be the legal representative of the Association and as such shall have full control of the management of the affairs of the Association, subject to the control of the Association in regular convention; it shall make the necessary arrangements for the convention and shall have power to expend the funds of the Association or to invest the same, but must not incur indebtedness beyond the funds in the hands of the Treasurer and Secretary. The Executive Committee shall have power to prepare and enforce, for the conduct of the business of the Association, by-laws not in conflict with this Constitution. It shall hold an annual meeting at least one hour before the opening session of each annual convention. Other meetings shall be held at the call of the President or of any three members of the Executive Committee.

All questions in the Executive Committee shall be decided by a majority vote and seven members shall constitute a quorum. The Executive Committee may vote by letter upon questions submitted by the President and Secretary.

SECTION 3. The Treasurer shall have charge of the funds of the Association, shall pay bills against the Association on order of the Finance Committee certified by the Secretary and shall make a report of the expenditures and of the funds of the Association at the annual convention.

SECTION 4. The Secretary shall be an Active Member of the Association. It shall be his duty to attend all conventions and meetings of the Association and of the Executive Committee; prepare the business and duly record the proceedings thereof. He shall see that all monies due the Association are carefully collected, and shall promptly pay the same to the Treasurer. He shall personally certify the accuracy of all bills or vouchers to the Finance Committee.

He shall, at the annual convention, make a report of the receipts and of the condition and affairs of the Association.

He shall conduct the correspondence of the Association and keep a full record of the same.

SECTION 5. The Editor shall have charge of the printing and distribution to all the members, of the Proceedings and Transactions of the Association and shall perform such other duties as are assigned to him by the Executive Committee.

The publications of the Association shall be copyrighted so far as is practicable and proper.

ARTICLE VIII

COMMITTEES

SECTION 1. There shall be three standing Committees, the Finance Committee, the Membership Committee and the Publication Committee. The members of each shall be appointed by the outgoing Executive Committee at the time of the Annual Convention. They shall serve for one year beginning with the close of the last day of the annual meeting or until their successors shall have been chosen. Additional Committees may be appointed at any time by the President on authority of the Association.

SECTION 2. The Finance Committee, which shall consist of three active members, shall audit and approve all bills before they shall be paid by the Treasurer. It shall examine the books of the Secretary and of the Treasurer, annually, or oftener, and shall audit the same and report upon the same to the Executive Committee. This Committee shall also have general supervision of

the finances of the Association, making such reports thereon to the Executive Committee as the exigencies of the case may require or as directed by the Executive Committee or by the Association at its annual meeting.

Section 3. The Membership Committee, which shall consist of three members, shall examine the qualifications of and vote upon all applicants for membership nominated in due form, and report its action to the Secretary.

Section 4. The Publication Committee, which shall consist of five members, one of whom shall be the Editor, shall have control of the publications of the Association and shall see that all publications and papers are edited before publication and, whenever possible, before presentation.

The committee may call to its aid members of the Association or others who have had special experience in the subject treated, to advise in regard to any paper, or to discuss the same, and may return any paper to its author for correction or amendment.

No papers containing matter either readily found elsewhere, especially advocating personal interests, carelessly prepared, purely speculative, or foreign to the purpose of the Association shall be accepted. The Committee shall prepare rules which, when approved by the Executive Committee, shall govern the preparation, presentation and publication of all papers and such other matters of similar nature as the best interests of the Association may require.

ARTICLE IX

Meetings

Section 1. The Annual Convention of the Association shall open on such Tuesday as the Executive Committee may designate, at nine o'clock, a. m., and at such place as shall be designated by the Association at the previous convention, the selection to be by ballot. The place receiving a majority of all votes cast shall be selected as the place of meeting. All members shall be entitled to vote.

Section 2. The Executive Committee shall have power to change the place of meeting as in its judgment the interests of the Association may demand.

Section 3. The date of the Annual Convention shall be fixed by the Executive Committee not less than seventy days in advance of the meeting, and such date shall be printed on all ballots for the nomination or election of officers.

ARTICLE X

Sections

Section 1. Local Sections may be established by the Executive Committee on receipt of a written request to that effect signed by twenty Active or Corporate Members of the Association, residing in territory within which the Local Section is desired.

Section 2. National Sections consisting of Engineers, Superintendents, Chemists and Bacteriologists, Accountants or other classes of persons included in the membership of the Association, may be established by the Executive Committee on the request of thirty members. Any member of the Association may register in any National Section of the Association in which he is interested.

Section 3. Such sections shall choose their own officers and committees and may make any rules for their government not inconsistent with the constitution and by-laws of the Association, but these rules must first be approved by the Executive Committee.

Section 4. Each Local Section may receive from the Treasurer of the Association, for local use, not more than twenty-five per cent of the annual dues paid to the Association by the members of said Local Section. The Treasurer of said Local Section shall forward to the Secretary of the Association his application indorsed by the presiding officer of the Section for such portions of said sum as may be needed; and upon receipt of such application the Secretary shall request the Finance Committee to authorize the Treasurer of the Association to pay such sum to the Treasurer of the Local Section. Said sum may be used by the Local Section only in payment of necessary operating expenses incurred by the section, such as printing, stationery, postage, rent and care of room, light, fuel, etc. At the end of each fiscal year the Treasurer of each Local Section shall certify to the Secretary of the Association the balance on hand of the funds received from the Association. This balance shall be returned tothe Association or shall be charged to the Local Section as a portion of its quota for the following year. No Local Section shall be entitled to draw upon the Association until such certification has been made, and its accounts audited by the Finance Committee.

Section 5. The presiding officer of each section shall be an Honorary Vice-President of the Association.

Section 6. Any section may be dissolved by the Executive Committee for good and sufficient reasons.

ARTICLE XI

General

Section 1. Any member may, with the concurrence of the presiding officer, admit friends to the meetings of the Association, but such persons shall not take part in the discussions without the consent of the convention; and the privilege of the floor can only be granted to a non-member by unanimous consent.

Section 2. The Secretary shall send notice to all members of the Association at least fifteen days before the annual convention, giving the titles of papers to be read and mentioning any special business to be considered at said convention.

ARTICLE XII

Amendments

Section 1. All proposed amendments to the Constitution shall be submitted in writing to the Executive Committee which at its discretion may bring them before the next Annual Convention of the Association but the Executive Committee must do so on the request in writing of five members of the Association.

Section 2. To pass an amendment to the Constitution, an affirmative vote of two-thirds of the members present and voting at said convention shall be required.

POWER FOR PUMPING DERIVED FROM REFUSE

By E. H. Foster

To those who have not followed the more recent developments in the method of disposal of city refuse, it will be somewhat of a surprise to learn that there are a number of places where a portion, if not all, of the steam used in driving steam pumps at water works pumping stations is derived from the heat resulting from the burning of the waste material collected by the scavenger wagons of the city. Indications are that this practice will become more and more common in this country during the years which are to follow.

As a result of the development in the incinerator method of disposing of mixed refuse in England and in continental cities, several plants have been installed in this country and, in all probability, the older and less sanitary methods which have hitherto been in vogue will gradually give way to this more modern method, particularly as our cities increase in size.

For the benefit of those who have not given much thought to this particular subject, it may be well to mention the different methods of disposing of city waste:

One is by burial on land which is later used for agricultural purposes; another is by reduction, which consists of treatment by one of various well known processes for recovering the oils and grease and making the residue into fertilizer; another is by incineration which consists of burning up of all the material at a high temperature, and a fourth is by a combination of reduction and incineration.

It will be evident that the burying method is only suitable for very small towns because of the great amount of land required to suitably conduct this system. It is also true that the reduction method can be used only where the process will be made to pay, as the system is expensive to install and, unless the quantities are large enough to show a fair profit, there is not sufficient inducement to justify this method. Only a portion of the refuse material collected can be so treated; therefore, a separate collection system must be maintained.

By separate collection a householder is required to maintain three receptacles, one for kitchen garbage, chiefly composed of cullings from vegetables and meats; another for general rubbish, such as paper, rags, old clothing, tins and sweepings, and a third for ashes alone as rejected from the household fires.

These different classes of material must be called for by three different sets of collectors, each having a different style of cart. Owing to its tendency to decompose, the garbage must be collected frequently, in summer time as often as once a day. In winter the garbage is apt to freeze in the can and is difficult to dislodge. It is also objectionable to carry through the streets; and the ashes, when they are transferred to the cart or carried through the streets, raise considerable dust, particularly on a windy day.

By the *Mixed-Collection* system, however, only one can is maintained by the householder and all the different materials are deposited therein. The moisture from the garbage is absorbed by the ashes; the tendency to decompose is modified and the dust does not fly when being tipped into the collecting wagon or when being unloaded therefrom. Also, one style of wagon may be used for the collection and one call from the collector, all of which advantages are greatly in favor of the mixed collection.

Mixed collection is also ideal for an incinerator because combustion is best maintained when the material is thoroughly mixed, but the incinerator must be one of high temperature. It must be of the type known as the Destructor type. It must burn the material without the use of additional fuel and it must maintain a temperature averaging 1600 degrees or 1800 degrees Fahrenheit, never falling below 1250 degrees Fahrenheit. This latter is a sanitary requirement and insures perfect combustion and freedom from odors. Only furnaces following the development of what is now known as the English Destructor practice are capable of fulfilling these requirements.

Likewise, in large cities where it is possible to maintain, to a large extent, a separate collection and where the amount of food refuse is sufficient to profitably maintain a reduction plant for the extraction of oil and grease and for the marketing of the tankage, incinerators will be required, to dispose of the dry rubbish and ashes and such miscellaneous material, amounting to fully three-fourths, by weight, of the total material collected.

It is evident that the production of heat is a necessary part of either system and, having produced the effect of destroying refuse

in a sanitary and inoffensive manner, the question of how best to utilize this heat then arises. The question is answered by combining a steam boiler with the furnace and producing steam at any desired pressure. Steam so produced is available for running engines to produce electricity but, as a rule, the amount of electricity which could be produced is but a small proportion of the total amount which is consumed by the community; also, the operation of the destructor does not lend itself to the requirements of peak loads which are incident to all lighting and power stations. A pumping load, however, is ideal for a destructor because of its uniformity and constancy, and it is in this direction that a municipality has its greatest opportunity for conserving this energy.

In many respects the requirements and the working conditions of a destructor and of a pumping station are parallel:

They should both be centrally located. They are frequently best arranged in subdivisions to serve districts. They are a public service feature which requires constant, steady operation. They may be combined under one superintendent, calling, as they do, for the same kind of experience and knowledge. The same applies to the employees, they may be interchangeable, for the same reason. Similar articles of supply are needed at both. Both should be scrupulously clean and sanitary in all their features; also, in the method of operation. An electric transporter and grab bucket are frequently used for transferring the refuse from a common receiving pit to feed hoppers of the destructor; the same apparatus is often required by water works for transferring coal, as received, to the storage hoppers. The facilities for disposing of ashes and clinker are also similar. Many economies may be effected to the municipality by the combination of these two equipments.

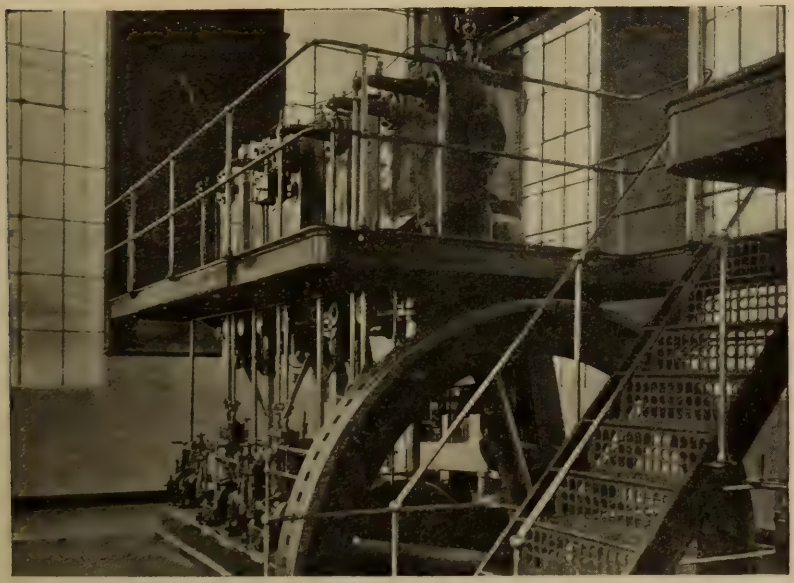
It would hardly be expected that the exact amount of steam available from the destructor would coincide with the exact amount of steam required at the pumping station, but the almost invariable condition is that the destructor steam is somewhat less than required by the pumps. Therefore, the difference is made up by auxiliary boilers.

It is evident that the steam may be passed direct from the destructor to the steam range of the pumping station or it may be converted into electricity and used to drive motor-driven pumps. Instances in this country where steam from a destructor is used directly for driving pumps are found at Montgomery, Alabama; Westmount, near Montreal; Ontario, and Savannah, Georgia, while instances where the power is first converted into electricity and then used to drive motordriven pumps are found at Milwaukee, Wisconsin, and Savannah, Georgia.

INTERIOR OF A REFUSE DESTRUCTOR SHOWING FRONT OF FURNACE INTO WHICH MATERIAL IS FED BY HAND

AN ENGLISH REFUSE DESTRUCTOR AND PUMPING STATION

HEENAN REFUSE DESTRUCTOR AT MONTGOMERY, ALA. THE STEAM PIPE SUPPORTED ON TRESTLE AT RIGHT OF BUILDING CARRIES STEAM FOR PUMPING STATION.



WATER WORKS PUMPING ENGINE OPERATED BY STEAM FROM A DESTRUCTOR

Refuse Destructor and Municipal Lighting Plant at Westmount, Quebec

Clifton Refuse Destructor, New York City

DISCUSSION

Mr. Theodore A. Leisen: Regardless of whether the water be pumped from deep wells or surface water, the power generated from the steam developed from the refuse can be used just as advantageously by transmitting the power thus derived through the medium of electric current, and when so transmitted it can be utilized at a pumping station remote from the incinerator without any danger of contamination from dust from the incinerating plant.

In order to decrease the length of the haul that is made necessary to reach the incinerating plant it is customary to locate the plant somewhere within reasonable and easy reach of the base of supply, which in this instance is the thickly inhabited section of the city, and on that account the most feasible proposition would seem to be to convert the steam into electricity, as stated, and then transmit the current to the point where it is required for pumping, regardless of distance.

ON THE VALUATION OF WATER WORKS' SPECIAL FRANCHISES

By Henry deForest Baldwin

THE PRIME REQUIREMENT

It is apparent that the value of the permission to occupy the streets may be worth less than nothing, or nothing, or have value, in accordance with the conditions prevailing at any particular time and place. The value of the franchise is actually the rental value of the use and occupation of the streets and can be determined by capitalizing the economic rent.

Mill, in his "Political Economy," book II, chapter 16, section 2, states the law of rent as follows:

> The rent, therefore, which any land will yield, is the excess of its produce beyond what can be returned to the same capital if employed on the worst land in cultivation.

Land which does not yield such excess yields no rent.

So also there cannot be a rental value of the use and occupation of the streets, except in cases where such use and occupation can be made to yield an excess of earnings beyond what can be returned to the same capital, if employed in operating a franchise which yielded merely a fair return to such capital.

The permission to occupy the streets cannot be worth anything, where the business carried on by the use of the street is not capable of being remunerative. To be remunerative, the business must yield a fair return on the amount invested, in addition to all necessary running expenses including depreciation.

SPECIAL FRANCHISE NOT VALUABLE DURING PERIOD OF CONSTRUCTION AND DEVELOPMENT

But the earnings can in no case be sufficient to meet such requirements at the very start. In the most profitable enterprises there will be the time necessary for construction, during which the plant cannot be operated and of course can produce no earnings. After

the plant commences to be operated, it always requires time to build up a business. A most notable example of this is a railroad through a new territory. It must necessarily run at a loss for many years. A familiar example is a large office building or apartment house, which usually requires several years to get full of tenants paying the fair rent of the building.

In the case of a water company this time is often a long period. Messrs. Benezette Williams and C. B. Williams, two distinguished engineers, in a recent report to the city authorities of Peoria, Ill., said as follows:

> It is found that water works plants that have been built and maintained of adequate size for the cities they serve, will take from five to fifteen years to acquire one dollar of private revenue per capita; they take from ten to twenty-five years to acquire two dollars of private revenue per capita; and to reach a really remunerative stage in revenue generally requires from twenty to thirty years.

Chief Judge Parker, in the case of Skaneateles Water Company v. Skaneateles, 161 N. Y., 154, 161, has expressed in a forcible way the experience of one company.

> It is the experience of all attempts to introduce water into villages and small cities that the number of individual patrons at the outset is very small, because their houses are not piped, and they are without bath tubs and other appliances, which go with the use of water supplied under pressure. The houses erected after the construction of water works, are, of course, made ready for connection with the pipes of the company; but the old houses are brought in very slowly; many never come in, while a small percentage of the others are brought in each year, as the owners find themselves able to enjoy the luxury afforded by the water sytem, or as they may be persuaded that the necessary expense ought to be incurred for reasons of health or comfort. This means in almost all cases losses for the first few years, until a sufficient number of people have become patrons to put the plant on a paying basis. The theory of the defendant seems to be that the proper way to treat such a corporation as the plaintiff, promoted in this instance, as it appears, by defendant's citizens, is to let it go on and build water works losing money each year while it educates the people up to the point of using the water, until years have passed away and the plant has at last come to a paying basis, and then duplicate its plant and take over a paying business for the simple cost of the construction of new works, and it claims the permission of the Legislature to take that very course.

Because the plant does not pay for many years after it is started, it does not follow at all that it was a foolish enterprise, properly involving loss upon the investors.

It is entirely reasonable to enter upon a commercial enterprise like a water company, knowing in the beginning that it could not meet all the commercial requirements for many years, because if it

is useful and of benefit to the community, it may be very certain that it will pay in the end, unless subjected to unfair treatment by the public authorities.

The best test—perhaps the only proper test—as to whether an enterprise undertaken by a public service corporation is so reasonable and proper as to entitle the investors to reasonable commercial remuneration is whether the public service rendered has been beneficial to the community and worth to the community what it has cost the investors. If it has, then the investors are certainly entitled to get their money back with a profit commensurate with the risk involved.

It should not be lightly assumed that the directors have been negligent in exacting too low rates for the service and thereby unduly increasing the period of development. It is not like a competitive business even though the franchise granted is not exclusive. It usually enjoys a practical monopoly. It may be good business policy to fix a low rate which will attract new customers and postpone the period of profits.

Except in rare cases all franchises now granted are subject to an expressed or implied condition that the service will be given at a reasonable rate, even though to do this requires a larger investment of capital to launch it.

A reasonable and just rate is one that is reasonable and just under the circumstances. It might be quite unreasonable, indeed it usually would be unreasonable, to fix a rate during the early years of operations, which would satisfy the requirements of running expenses, taxes, depreciation, interest and profits. The operating expenses, taxes and interest during construction must be met, as incurred, if the work is to go on. This is also true of the annual interest on that part of the capital represented by bonds, although it is quite common to defer a part of the interest charges by issuing bonds at a lower rate of interest than the market rate for such an enterprise, and accepting less for them than their face value. But from the standpoint of the consumer it might be properly argued that the requirements of the depreciation account and the discounts on the bonds, which are merely deferred interest, might be properly postponed until the business had developed.

If the community were doing the work itself, instead of seeking the aid of private capital, it would certainly adopt a rate in the beginning which would fall very much short of yielding a return to satisfy all the requirements of a successful commercial enterprise.

If it paid operating expenses and annual interest charges, it could go on, leaving it for the future to take care of the depreciation and profits. The city of New York, during the first fifty-two years of its water supply system, spent for construction $37,382,521.25 and for maintenance and interest charges $38,564,592.61, making expenditures amounting to $75,947,113.86, and received for its service less than $42,000,000, leaving a net profit of a little over $3,000,000, which certainly would not be sufficient to meet the depreciation on the depreciable assets employed in the enterprise. (Water Supply of the City of New York: The Merchants' Assoc., 1900, p. 550.)

Deferring the amortization of deficits caused by depreciation, discount on bonds and loss of return on that part of the investment represented by the stock is one of the conditions of all enterprises of the kind we are considering. Temporary renunciation on the part of the stockholders is almost always necessary in every business. But the claims of stockholders are usually recognized, at least partially, before the deficits from depreciation and discounts are provided for.

These deficits suffered during the years of development constitute a part of the cost of establishing the business.

Issuing bonds at a discount is a device adopted for the purpose of postponing the burden of an excessive interest charge from the earlier years to a later period, when the enterprise has become more developed and a more profitable business acquired, and is often properly used to permanently, or for a long period, capitalize a part of the cost of establishing the business.

The adjustment of the depreciation account can always be deferred, because the effect of the depreciation is itself deferred. The pipes, equipment and structures become older and therefore less valuable than when installed, but they, in great part, remain capable of performing the service for which they were intended for many years. To be sure, this is not true of all of the depreciation account, particularly in the case of a growing company. There is a functional depreciation as well as a material depreciation. This element is greater in a company operating in a growing community. It puts in a 2-inch pipe to serve a few houses. That pipe has to be replaced by a 6-inch pipe when the street has been built up. The replacement may take place in one year or in twenty years. No one can foresee with certainty. It puts in a pump capable of delivering a certain number of gallons of water. When the demands upon it

increase, a larger pump has to be purchased, and the first pump is carried at a greatly decreased value, as an auxiliary. The increased cost of a pipe, larger than is immediately necessary, carried for a number of years, together with the material depreciation going on in it, will often offset the disadvantage of having to pull up a pipe in good condition, because it is too small, a few years after it is put in, to replace it with a larger one. The wisest course in any given case is a business question. It may make for the greatest economy to put in a small pipe and take it up in a few years, although it may be still in good condition, and replace it by a more expensive and larger pipe.

The privilege of being allowed to do the business cannot be said to possess value until the business is developed to the point where it yields enough to return to investors who have conducted it properly, enough to satisfy all deficits from depreciation, deferred interest and the failure to yield a fair profit on the sums necessarily invested, or at least to pay a return on these deficits capitalized as "going-value", and something more. Until then the value of the permission is merely speculative, and depends not only upon the commercial possibilities of the business conducted on the principle of charging all the traffic will bear, but also upon the chance of being allowed to charge for the service in excess of what would yield a fair return on the investment—which chance in these days of an aroused public opinion and of public service commissions must be conceded to be small. For the value of the business depends on the rates received for the service, and rates are subject to public regulation. Indeed the value of the permission to operate a franchise might be properly termed the capitalization of the extent to which the operator is allowed to charge a rate beyond what is a reasonable return on the capital invested.

A fair inquiry, then, into the value of the permission to operate a special franchise necessarily involves something more than a comparison of the depreciated value of the plant, the operating expenses and the earnings. Such an inquiry would be much easier if there were a uniform method of keeping accounts adopted by such enterprises, but until there is public regulation of accounts, it is absolutely necessary in fairness to consider the financial transactions of the enterprise, if not from its beginning at least for a series of years. Important matters to be investigated are the following: 1. Has the enterprise passed beyond the development period; 2. The extent of the depreciation in the plant; 3. The cost of reproducing the

same or an equally efficient plant; 4. The cost of acquiring the business and the "going-value."

DEPRECIATION AND THE OBLIGATION TO RENEW

The extent of the depreciation of the plant used to operate a special franchise, while an important subject for investigation, does not affect proportionately the value of the permission to do the business.

The operation of the franchise must be considered as a business which is to go on and not stop.

If it is to go on, the parts which are wearing out and in the future are to become entirely worn out, will have to be renewed. The operator of the plant has upon him the obligation to renew as renewals become necessary. He has assumed the duty of operating the franchise and may be required by public authority to keep the plant in such condition as to satisfactorily perform its service.

Although the expenditures for renewals are always to some extent and for a time are almost wholly deferred, it is a continuous increasing liability which is necessarily assumed by the owners of the franchise with their obligation to operate the franchise. It is as much a liability as is the bonded indebtedness. The date when a bond is to become due is fixed. The time when a depreciating article is to be renewed is more or less uncertain, but it is just as certain to arrive as is the day when the bond must be paid.

The extent of this liability at any given time is measured by the extent of the depreciation. Usually the depreciated value of the tangible assets is arrived at by starting with the cost of reproduction and then making deduction for age and inappropriateness. Frequently this liability is partially represented on the balance sheet in a depreciation account, but whether it is so represented or not, it always exists as a fact.

The value of the enterprise depends not only on the earnings and the value of the tangible assets, but also on the amount which the owners will be called upon to expend to continue the operation of the franchise.

An old plant, still capable of rendering satisfactory service, but nearing the period when it must be renewed, whose earnings are no more than sufficient to give a fair return on an amount equal to its depreciated value (i. e. cost less depreciation), could not be worth such an amount; because a purchaser would assume with his purchase an obligation to renew the depreciating parts as they

became worn out. He would acquire a depreciated plant burdened with an obligation to expend money on renewals. To make such a purchase attractive or even reasonable, the purchasers of the depreciated plant would have to see earnings on the depreciated value plus the cost of renewals, namely, the depreciation.

In assuming value for the permission to do the business, we must assume that it would be commercially remunerative to invest in the enterprise, at the time of the inquiry, the full cost to reproduce an equally efficient new plant and the existing business. If the enterprise is to continue on a commercial basis, it must earn a return on the purchase price and enough more to compensate for the liability to renew; otherwise it would not pay to renew, as renewals are required. Permission to engage in an enterprise which it would not pay to start by an investment of the cost to reproduce the necessary equipment must be valueless.

If the earnings are enough to supply a sinking fund which will be sufficient to meet the liability to renew as it becomes due, the sinking fund, though it be in outside securities, is a part of the capital invested in the enterprise. None of its earnings are available to its owners because all of the earnings are needed for the fund. The money put into the fund has not been taken from the business, but has been kept in the business to renew the plant when the time to renew shall have arrived. If the fund is entirely equal to the demands upon it, it will, at any stage of the company's development, amount to the difference between the actual depreciated value of the assets necessarily used in the enterprise and the cost to reproduce them new. As part of the plant is discarded owing to functional depreciation, the fund is drawn upon to the extent of the cost of the discarded part and the amount thus withdrawn is released. As renewals due to the wearing out of needed parts become necessary, the fund is drawn upon to supply the renewals. If the fund is perfectly kept, the plant and the fund, together, should at all times equal the cost of reproduction.

If such a sinking fund is protecting a growing business, it would doubtless be loaned to the business and used to acquire assets beyond what is needed for the replacement of discarded parts and renewals. In such case it would take the place of what would otherwise be obtained by issuing new capital securities. It would be accounted for separate and apart from the other capital during the sinking fund period. From the point of view of the enterprise it is really borrowed money. The earnings from it would have to be accounted

for to the fund—not to the owners, just as interest to be paid for borrowed money. Hence investing the fund in the business itself does not make a different situation from the case presented where it is invested in outside securities. In both cases equally the sinking fund is kept invested in the business. It cannot itself earn any return for the owners, because its earnings are needed for its own accretions. If the owners are to receive any return on its account as part of the capital invested in the business, that return must be found in the earnings of the business itself after providing the proper interest upon the amount invested in the sinking fund.

If the business does not pay a return on the amount in the sinking fund sufficient to keep it up, as well as a fair return upon the cost of the original plant, it is being conducted at a loss.

The more usual method of recognizing depreciation in the bookkeeping of a water works enterprise is known as "the straight-line method," that is to say, writing off such a gross sum for depreciation each year, as experience has shown to be adequate. The bookkeeping difficulties of actually applying the sinking fund method of taking care of depreciation, in the case of a company serving a growing community which is obliged to make large increases in its plant every year, are so great in actual practice, that it is rarely, if ever, resorted to. If the straightline method of providing for depreciation could have been and has been consistently employed from the beginning of the enterprise, and the amount attributed to that account each year has been left in the account and not distributed in the various construction accounts, except as renewals are made and as parts of the plant are discarded, such depreciation account will show accurately the extent of the liability for renewals. To the extent that the amount written off from earnings for depreciation is not needed for renewals, it will be used for additions, and takes the place of what would otherwise have been obtained by the issuance of new capital securities. It represents an actual increase in the size of the plant. If it is not needed for renewals or additions, it would have to be invested in outside securities. This, then, presents the same situation as where the depreciation is taken care of through maintaining a sinking fund.

Now, if the amount which should be taken out of earnings and invested in a sinking fund or credited to the depreciation account to maintain the capital intact has actually been distributed to stockholders in dividends, this could not affect the liability resulting from the need of renewing the depreciating parts of the plant.

That liability continues. The due day is sure to come. Providing against it by a sinking fund or a depreciation account may be an exercise of financial prudence, but it neither takes away from nor adds to the extent of the liability. It neither hastens nor retards the time when expenditures for renewals are necessary. If all extensions and additions are provided for by the issuance of new capital securities there will come a day when the expense of renewals must be met. This situation is so often dealt with by issuing new capital securities, that it has now become practically the universal rule to disregard entirely the capitalization of a company, where an inquiry into its affairs is necessary, and to investigate merely its actual property. The issuance of securities—stock and bonds—is treated as a matter merely affecting the owners and their creditors and having no bearing on the value of the business. This being so, it makes no difference how a depreciation account has been kept or whether such account at all has been kept. Whatever is done in that regard cannot affect the value of the franchise. The book-keeping methods of the company have nothing to do with that. A purchaser of a going business, where a sinking fund or depreciation account had been provided, would get the depreciated plant and a sinking fund ready to meet the demands for renewals. If no such fund or account had been provided the purchaser would get the depreciated plant and the liability to renew it out of new money as it wore out. The extent of this liability would equal the difference between the value of the plant and its cost of reproduction. In either case the value of the privilege of doing the business would be the same. In either case the earning capacity of the business would be the same. In either case the earnings would have to pay a fair return on the cost of reproduction to make the plant worth its depreciated value.

It is a matter of common knowledge that a property made up of many parts not only can be operated after many of the parts have suffered depreciation, but always is so operated. Though each particular depreciating article will sometime have to be renewed, the plant must inevitably consist of parts more or less depreciated. The difference between actual value and the cost of reproduction at any particular time will always be a comparatively large amount—probably between 25 and 40 per cent of the cost of reproduction, if the plant is maintained in an efficient condition. It is quite frequent to hear criticisms of corporate management that the property has been kept in good condition or has been allowed to run down, as the

case may be. To a certain extent, interest charges, and even dividends, may be maintained at the expense of keeping the property in a rundown condition. But where such policy is pursued beyond a certain point increased expenditures upon the property must be made later on. The value of the service rendered is not affected by this, excepting so far as the service may become less efficient. The earning capacity of the business may not be diminished by this, unless operating expenses may be thereby increased and patronage driven away. All such considerations, while important to the stockholders and creditors, can only indirectly affect the value of the permission to operate the franchise.

The value of the permission to do the business cannot vary with this depreciated value. If the plant is allowed to run down the permission is not worth more. If the plant is kept up in an extravagant way the permission to do the business is not worth less. The age of the pumps of a water company, so long as they do their work, cannot affect the value of the service rendered nor the value of the permission to render the service. Possibly, to the extent that they are inefficient, they affect operating expenses by increasing them. Pipes which, under the conditions prevailing, cannot be used more than another year, either because of their liability to burst or because they are too small for increased demands, are still doing the same work as they did when they were new. They are less valuable to the owners than new pipes, but their depreciation has no bearing on the value of the permission to do the business. The greater the depreciation, the greater and more important is the liability to renew. To compare net earnings with depreciated value in seeking the value of the enterprise, is unsound, illogical and can only lead to an incorrect result. The correct factor with which to compare net earnings in such an inquiry is the cost of reproduction new. This can be always accurately known, and correctly represents the investment in tangible property, which would be necessary, in order to operate the franchise, at the time to which the inquiry is directed.

COST OF REPRODUCTION NEW IS THE PROPER FACTOR

It might be urged that, in a well-managed business, the liability to renew the plant as it wears out will never call for payment in full, so long as the business is a going business, and that the difference between the actual cost (or the cost of reproduction) and the depreciated value at any particular time could be properly withdrawn from the business and returned to the stockholders and the capital

correspondingly reduced. But this would be possible only in those cases where the enterprise has yielded, not only a return on the capital invested, but has also provided for this depreciation. In all such cases there must exist large earnings. Until that investment of capital represented by the difference between the cost of reproduction and the depreciated value has been returned to the investors, they must be allowed to earn upon it or they are deprived of a fair return.

This difference between cost and depreciated value might be treated as permanently separated from the accounts in which the tangible assets are carried, and a corresponding amount credited to the cost of establishing the business and carried in the inventory as a part of the "going-value."

In the case of Shepard v. Northern Pacific R. Co. (1911), 184 Fed. Rep., 765, Judge Sanborn, in the United States Circuit Court, handed down a decision in which he held that interest on the cost of reproduction of railroad property at 4 per cent per annum during one half the time requisite to acquire and construct it is a necessary expense of reproduction, and that the cost of reproduction new, with a large addition for the solidification and adaptation of the business and without any deduction for depreciation, was a proper factor with which to compare net earnings in a rate case.

If to operate the franchise requires the investment of capital in a plant equal to the cost of reproduction new of the existing plant, the value of the privilege cannot increase through the wearing out of the plant, because as the plant wears out, a liability attaches to renew. The liability is not affected by the earnings. It exists in every case, whether the plant pays or does not pay; whether the owner is compensated for the liability or whether he is not compensated for it.

It follows that in an investigation of the value of the privilege of operating a franchise the cost of reproduction new of the assets necessarily employed and not their depreciated value should be used as one of the factors with which to compare the net earnings.

GOING-VALUE

We will now take up the question of "going-value" and cost of establishing the business.

We have seen how, in the usual case, the deficits incurred during the years of development constitute a part of the cost of establishing the business. Of course, the investment of capital necessary to establish the business might be met by the issue of new securities.

In such a case such investment would be represented on the balance sheet. It would also be represented on the balance sheet, in so far as the discount on bonds and the depreciation of the plant have not been written off. But, whether represented on the balance sheet or not, such investment is as much new capital put into the business as is the money spent for pipes and pumps, and should be treated as a capital investment, and if it does not exceed the value of the acquired business may properly be continued as such without being written off. The established business may be more enduring than the plant. The cost of establishing the business can be easily ascertained. In an inventory and appraisal, the result of this investment, if capitalized, appears as "going-value" or "going-concern-value," which, unless there has been mismanagement, should in the ordinary case equal the cost of establishing the business, just as the cost of the company's pumping station and distribution system, if reasonably incurred, should be used as a starting-point in estimating their value. An analogous case is that of a business depending largely on advertising. The amount spent for advertising is capital invested in the enterprise, and should be worth all it has cost. Like capital invested in advertising, the "going-value" created by wise expenditure may be subject to a relatively large depreciation.

A business may have a "going-value," even though it does not pay a fair return on the amount necessarily invested in its tangible property. If the enterprise has any business at all and has necessarily expended capital to acquire it, however small it may be and however insufficient it may be to pay an adequate return on the investment, the capital so expended is a part of such investment.

If the enterprise is of such a character that it was practically remunerative from the start, it would not require the investment of capital to acquire the business, and hence the cost of establishing the business would be nothing. If the same conditions exist at the time to which the inquiry is directed as existed when the enterprise was thus started, there would be no "going-value." The intangible value would be in the permission to do the business. But this is the only kind of business which has not a "going-value" representing an investment of capital.

If the "going-value" is equal to or exceeds the depreciation, carrying the depreciated assets on the books at their cost or at the cost of reproducing them new would not amount to an overcapitalization. As a practical matter the "going-value" is apt to be

partially carried on the balance sheet by not recognizing there the depreciation of the plant, although the cost of establishing the business is usually a greater amount than this depreciation.

It follows that a fair use of the relation between net earnings and the value of the property embarked in the enterprise requires that consideration should be given to the reasonable cost of establishing the business, and the investigation seeking this cost must go beyond a mere inspection of the balance sheet or a mere appraisal of the plant. It should cover a number of years.

We believe this is so in every case. But it is more obviously so in a case where a company is still in the development period and has not reached the point where it pays a return on the capital necessarily and properly invested in the plant.

The courts have not yet pointed out how "going-value" should be computed. Until some rules are laid down, the length of the taxing-officer's foot, or perhaps the vigor of his imagination or some equally arbitrary standard, will continue to be used. Any fair rule for estimating "going-value" must take into consideration, either the actual cost of establishing the business, or what it would cost at the present time to reproduce both the plant and the business.

"GOING-VALUE" IS MEASURED BY COST OF ESTABLISHING BUSINESS

The cost of establishing the business seems to be the primary factor used by the Wisconsin State Commission in estimating "going-value." This commission has won general approval for its fairness and wisdom, and its nine volumes of reports are the most illuminating and instructive source of information relative to the methods to be pursued in the public regulation of corporations and the analysis of their finances that our official literature affords. In Payne v. Wisconsin Telephone Co., a rate case decided in August, 1909, this commission had the following to say on allowing for "going-value" (4 Wisc. R. R. Com. Rep., 60):

> If property is devoted to the public use and reasonable care has been exercised in all the phases of its management, but the owners have not yet received a fair return during the earlier years of the operation of the plant in which the property is used for the convenience of the public, the deficits thus incurred must be made up out of later earnings in so far as this is commercially possible and expedient.
>
> In other words, every effort honestly put forth, every dollar properly expended and every obligation legitimately incurred in the establishment of an efficient public utility business must be taken into consideration in the making of rates for such business. Collectively, the elements just referred to may be designated by

the term "going-value" and in this sense there can be no question regarding the propriety and justice of admitting "going-value" as a consideration in the determination of rates. Whether this "going-value" should be made a part of the permanent capitalization of the plant or provided for by means of a sinking fund, or other fund, is a matter to be decided on the facts of each particular case. If it is made a part of the capital investment, it becomes a permanent charge against consumers for all time to come. If it is provided for by means of a sinking fund, all persons who are patrons of the plant during the period in which the sinking fund is accumulated will alone contribute.

In the case of Hill v. Antigo Water Company, the commission discuss very fully the whole theory of valuing water-company property for ratemaking purposes (3 Wisconsin Com. Rep., 623). This entire case is well worth reading. It was held that:

The investors in the plant and those who carry on its business are equitably entitled to reasonable returns for interest and profits on a valuation that fairly represents the legitimate and necessary costs of constructing the plant and of building up its business. . . . Of the physical plant alone the most equitable valuation for rate-making purposes appears to be best represented by the original cost of the plant and by the cost of reproducing it. . . . Of the business alone of the plant the valuation that is most equitable for rate-making purposes appears to be best represented by the losses during the earlier years or by the deficits from operation during the development period.

On this last subject the commission said, page 706:

But new plants are seldom paying at the start. Several years are usually required before they obtain a sufficient amount of business or earnings to cover operating expenses including depreciation and a reasonable rate of interest on the investment. The amount by which the earnings fail to meet these requirements may thus be regarded as deficits from the operation. These deficits constitute the cost of building up the business of the plant. They are as much a part of the cost of building up the business as loss of interest during the construction of the plant is a part of the cost of its construction. They are taken into account by those who enter upon such undertakings, and if they cannot be recovered in some way the plant fails by that much to yield reasonable returns upon the amount that has been expended upon it and its business. Such deficits may be covered either by being regarded as a part of the investment and included in the capital upon which interest is allowed, or they can be carried until they can be written off when the earnings have so grown as to leave a surplus above a reasonable return on the investment that is large enough to permit it. When capitalized, they become a permanent charge on the consumers. When charged off from the surplus, they are gradually extinguished. . . . The investors fully expect, and in most cases rightly so, that these losses will be made good as soon as warranted by the business of the plant. They usually regard such deficits as an additional investment upon which, unless the whole amount is refunded to them in some form, they are entitled to the same returns as on the rest of their capital. Unless they are so compensated, it is manifestly clear that no money from private sources is likely ever to be invested for such purposes, except, perhaps, in a few

rare instances for philanthropic reasons. . . . The total investment consists of the cost of the plant, of its business and of its franchise. . . . It thus appears that the cost of building up the business of a plant is in most cases as unavoidable as the cost of the construction of the plant itself; that when such costs are incurred, they must be reimbursed in some form by the consumers in order that capital may be secured; that such reimbursement is equitable as between investors and consumers, and that this is a just method of dealing with such costs for other reasons. If this is sound, it also follows that the cost of the business must also be taken into consideration in determining the value of the plant for ratefixing purposes. . . . It will probably be found that in most cases it is far better to include these costs in the capital than to attempt to wipe them out in a comparatively brief period through some system of amortization. These costs, as shown, are in the nature of an investment and should therefore, it would seem, be treated as such.

"GOING-VALUE" A WELL-RECOGNIZED ELEMENT

If allowance for the investment of capital in building up the business is made in rate cases, far more should it be made in appraising the value of the permission to do the business.

The courts have recognized "going-value" as distinguished from "good-will" and "franchise value." As was pointed out by the Wisconsin Railroad Commission in the Payne case and Hill case, above referred to, "good-will is an attribute of a competitive business." In Bristol v. Bristol Water Works, 23 R. I., 278, it is said:

A monopoly has no good-will, for its customers are retained by compulsion, not by their voluntary choice.

In the Consolidated Gas case it was also pointed out by the court that in the case of a monopoly there can be no good-will. In all of the following citations the element both of good-will and franchise value is disregarded and the discussion is confined to a quite separate element of value, namely, "going-value."

A recent case on "going-value" is The City of Omaha v. Omaha Water Company, decided by the Supreme Court of the United States on May 31, 1910 (218 U. S., 180). Judge Lurton delivered the unanimous opinion of the court. The case was one for specific performance, the water company having sued the city of Omaha for a judgment requiring it to carry out the purchase of its property, the value of which had been fixed by appraisers. The distinction between "going-value," "good-will" and franchise value is shown in this case. In his opinion, Mr. Justice Lurton said (p. 202):

The appraisers in making their estimate of valuation included $562,712.45 for the "going-value." . . . The option to purchase excluded any value on account

of unexpired franchise; but it did not limit the value to the bare bones of the plant, its physical properties, such as its lands, its machinery, its water pipes or settling reservoirs, nor to what it would take to reproduce each of its physical features. The value in equity and justice must include whatever is contributed by the fact of the connection of the items making a complete and operating plant. The difference between a dead plant and a live one is a real value, and is independent of any franchise to go on, or any mere good-will as between such a plant and its customers. That kind of good-will, as suggested in Wilcox v. Consolidated Gas Co., 212 U. S., 19, is of little or no commercial value when the business is, as here, a natural monopoly, with which the customer must deal, whether he will or no That there is a difference between even the cost of duplication, less depreciation, of the elements making up the water company plant, and the commercial value of the business as a going concern is evident. Such an allowance was upheld in National Water Works v. Kansas City, 62 Fed., 853, where the opinion was by Mr. Justice Brewer. We can add nothing to the reasoning of the learned justice, and shall not try to. That case has been approved and followed in Gloucester Water Co. v. Gloucester, 179 Mass., 365, and Norwich Gas Co. v. City of Norwich, 76 Conn., 565. No such question was considered in either Knoxville v. Knoxville Water Co., 212 U. S., 1, or in Wilcox v. Consolidated Gas Co., 212 U. S., 19. Both cases were rate cases, and did not concern the ascertainment of value under contracts of sale.

The National Water Works Company v. Kansas City, 62 Fed. Rep., 853, referred to in the Omaha Water Company case, was also a case where the franchise of the company had expired. The city was obliged, or had the right, to purchase the works and was obliged to pay "the fair and equitable value thereof." The Circuit Court found this equitable value to be $2,714,000. The Court of Appeals, Judge Brewer writing the opinion, found $3,000,000 as the value of the water works, exclusive of the franchise. In the transactions of the American Society of Civil Engineers, No. 813, there is a discussion of this case, in which some of the commissioners took part. It appears from this that in the original appraisal there was an allowance made for "going-value" measured by interest on the estimated amount necessary to replace the plant during the time which would reasonably be required for construction, and by the further allowance of interest on this amount for such additional time as would probably be required to work up the business to the same standard as that found at the time of the transfer; but notwithstanding this the Court of Appeals added nearly three hundred thousand dollars to whatever the commissioners had already allowed for "going-concern" value. Judge Brewer, in the opinion in the Court of Appeals, said (p. 864):

The company insists that the test is to take the income or earnings and capitalize them. The earnings pay 6 per cent on $4,500,000. In other words, the company

has produced a property which earns 6 per cent on four millions and a half; and that, it is claimed, is the fair valuation of the property, 6 per cent being ordinary interest. On the other hand, the city insists that the franchise has ceased, and that basing the value upon earnings is in effect valuing a franchise which no longer exists, and which the city is not to pay for; that the true way is to take the value of the pipe, the machinery and real estate, put together into a water works system, as a complete structure, irrespective of any franchise—irrespective of anything which the property earns, or may earn in the future. We are not satisfied that either method by itself will show that which, under all the circumstances, can be adjudged the "fair and equitable value." Capitalization of the earnings will not, because that implies a continuance of earnings, and a continuance of earnings rests upon a franchise to operate the water works. The original cost of the construction cannot control, for "original cost" and "present value" are not equivalent terms. Nor would the mere cost of reproducing the water works plant be a fair test, because that does not take into account the value which flows from the established connections between the pipes and the buildings of the city. It is obvious that the mere cost of purchasing the land, constructing the buildings, putting in the machinery and laying the pipes in the streets—in other words, the cost of reproduction—does not give the value of the property as it is today. A completed system of water works, such as the company has, without a single connection between the pipes in the streets and the buildings of the city, would be a property of much less value than that system connected, as it is, with so many buildings, and earning, in consequence thereof, the money which it does earn. The fact that it is a system in operation, not only with a capacity to supply the city, but actually supplying many buildings in the city—not only with a capacity to earn, but actually earning—makes it true that "the fair and equitable value" is something in excess of the cost of reproduction. The fact that the company does not own the connections between the pipes in the streets and the buildings—such connections being the property of the individual property owners—does not militate against the proposition last stated, for who would care to buy, or at least give a large price for, a water works system without a single connection between the pipes in the streets and the buildings adjacent. Such a system would be a dead structure, rather than a living and going business. The additional value created by the fact of many connections with buildings, with actual supply and actual earnings, is not represented by the mere cost of making such connections. Such connections are not compulsory, but depend upon the will of the property owners, and are secured only by efforts on the part of the owners of the water works, and inducements held out therefor. The city, by this purchase, steps into possession of a water works plant—not merely a completed system for bringing water to the city, and distributing it through pipes placed in the streets, but a system already earning a large income by virtue of having secured connections between the pipes in the streets and a multitude of private buildings. It steps into possession of a property which not only has the ability to earn, but is in fact earning. It should pay therefor not merely the value of a system which might be made to earn, but that of a system which does earn. Our effort has been to deduce from the volume of testimony that which, in this view of the situation, can be safely adjudged "the fair and equitable value." The original cost of the works is not accurately and satisfactorily shown. If it would have assisted us in reaching a conclusion—if, in

consequence of our ignorance thereof, we have not placed the value upon this property which it deserves—the company is alone to blame, for by the production of its books it could have clearly shown the actual cost of every part and of the whole of this property.

In Kennebec Water Dist. v. Waterville, 97 Me., 185; 60 L. R. A., 868, the court comments as follows:

But the term "good-will" may be misleading. Lord Eldon said that "good-will" is nothing more than the probability that old customers will resort to the old place. Cruttwell v. Lye, 17 Ves. Jr., 335. . . . Under any possible definition, it involves an element of personal choice. This phrase is inappropriate where there can be no choice. So far as the defendant's system is "practically exclusive," the element of "good will" should not be considered.

* * * * *

The defendants, in request 9, ask that in determining the amount to be added to structure value, in consideration of the fact that the system is a going concern, the appraisers should consider, among other things, the present efficiency of the system, the length of time necessary to construct the same de novo, the time and cost needed after construction to develop such new system to the level of the present one in respect to business and income, and the added net incomes and profits, if any, which, by its acquirement as such going concern, would accrue to a purchaser during the time required for such new construction, and for such development of business and income. We think this instruction should be given. These are all proper matters for consideration "among other things." They are not controlling. Their weight and value depend upon the varying circumstances of each particular case. Of course a plant, as such, already equipped for business, is worth more, if the business be a profitable one, than the mere cost of construction (p. 217).

In Gloucester Water Supply Company v. Gloucester, 179 Mass., 365, Loring, J., said:

It is plain that the real, commercial, market value of the property of the water company is, or may be, in fact, greater than the "cost of duplication, less depreciation, of the different features of the physical plant." Take, for example, a manufacturing plant: Suppose a manufacturing plant has been established for some ten years and is doing a good business and is sold as a going concern; it will sell for more on the market than a similar plant reproduced physically would sell for immediately on its completion, before it had acquired any business.

In Metropolitan Trust Company v. Houston and Texas Central R. Co., 90 Fed. Rep., 683, 687, 688, 689, it was held that a mere estimate of the cost of replacing the physical structure of the road is too narrow a basis upon which to determine its value, as the capital on which its owners are entitled to earn dividends, and as the basis for the fixing of rates by the state. McCormick, Circuit Judge, in his opinion, said:

It seems to be clear . . . that in estimating the value of this railroad property no allowance was made for the favorable location of the same, in view of the advance and prosperity of the country through which it runs, and the increment to its value due to the settling, seasoning and permanent establishment of the railways, and to the established business and the good will connected with its business, which has been established through a long series of years, and all of which ought reasonably to be considered in fixing the value of the property and the capitalization upon which at least it is entitled to earn, and should pay, some returns by way of interest or dividends. . . . This road . . . has established a business that would not and could not be disregarded in estimating the value of the railroad, if considered solely as a business property and venture. It cannot be so considered because of its quasi-public nature. Its duties, its obligations and its liability to control are elements that must be considered. As popularly expressed, the rights of the people—the rights of shippers who use it as a carrier—have to be regarded; but, as judicially expressed, these last have to be so regarded as not to disregard the inherent and reasonable rights of the projectors, proprietors and operators of these carriers. . . . And a system of rates and charges that looks to a valuation fixed on so narrow a basis as that shown to have been adopted by the commission, and so fixed as to return only a fair profit upon that valuation, and which permits no account for betterments made necessary by the growth of trade, seems to me to come clearly within the provision of the fourteenth amendment. . . . Promoters and proprietors of roads have looked to the future, as they had a right to do, and as they were induced to do by the solicitation of the various communities through which they run, and by various encouragements offered by the state. The commission, in estimating the value of these roads, say that they included interest on the money invested during the period of construction. This is somewhat vague, but the "period of construction" mentioned is probably limited to the time when each section of the road was opened to the public for business. And even if extended to the time when the road was completed to Denison and to Austin in 1873, nearly twenty years after its construction was begun at Houston, it would not cover all of the time, and possibly not nearly all of the time, in which the railroad company and its predecessors have lost interest on the investment. The estimate made on behalf of the railroad in this case of the cost to that company and to its predecessor company of the railroad property, and the business of that company as it exists today, may not be exactly accurate—clearly is not exactly accurate; but it seems to me that it is not beyond the fair value of the property, as it is shown to have been built up and constituted, and to exist today as a going business concern, and that such rates of fare for the carriage of persons and property as are reasonable, considered with reference to the cost of the carriage and the value of the carriage to the one for whom the service is rendered, cannot be reduced by the force of state law to such a scale as would appropriate the value of this property in any measure to the use of the public without just compensation to the owners thereof. . . .

The following cases also deal with "going-value."

Newburyport Water Supply Co. v. City of Newburyport, 168 Mass., 541;
Cedar Rapids Water Co. v. City of Cedar Rapids, 118 Iowa, 234;

Spring Valley Water Works v. San Francisco, 124 Fed. Rep., 574, 594 (1903); 165 Fed. Rep., 667, 693–696 (1908);
Venner v. Urbana Water Works, 174 Fed. Rep., 348, 352.

It is clear, then, that a water company's special franchise can have a value only after it has been allowed reasonable earnings on the cost of reproducing its plant new and complete, and on the "going-value" which represents an investment equal to the cost of establishing the business, including the deficits incurred during the period of construction and development.

A SIMPLE HYPOTHETICAL CASE TO ILLUSTRATE THE ARGUMENT

For illustration, assume a business with an equipment which cost $100,000 and which will give out completely, like Dr. Holmes' "One-Hoss Shay," in twenty years. Of course, in practice, the various parts have different periods of usefulness, but the principle is the same as though all gave out together, only we should have to consider each of such parts separately. As we will assume at first that there are no additions to the equipment, the depreciation can be taken care of conveniently by a sinking fund. Any book of interest tables shows that a dollar invested every year in a sinking fund which earned four per cent would produce at the end of twelve years $15.0258, and at the end of twenty years $29.7781. To produce $100,000 at the end of twenty years, the annual payment to the sinking fund will have to be $3,358. The payments of this amount each year with the earnings will produce a fund of $50,456.64 at the end of the twelfth year. We assume that the earnings commence at about 5 per cent of the cost and the operating expenses at 50 per cent of the gross earnings; that the gross earnings increase $1000 a year during the entire twenty years, and the operating expenses, while increasing in amount, gradually diminish in proportion to the gross earnings until, at the end of ten years, they are 30 per cent of the gross earnings, and continue at that rate; and assume that half of the cost is met by an issue of $50,000 of 5 per cent bonds.

At the end of the first year the business pays the operating expenses and the interest on the bonds, but can contribute nothing to the sinking fund.

At the end of five years the gross earnings are $9000, the operating expenses $3300, and the interest $2500, leaving for the sinking fund $3200. This amount is insufficient to meet the annual payment called for by the sinking fund.

At the end of ten years the gross earnings amount to $14,000 and the operating expenses and interest to $6800. This leaves to be applied to the depreciation account $7200—more than enough for that purpose, if it were not for the fact that arrears have to be paid up, and not only arrears of annual payments, but arrears in the earnings on annual payments, so that there is still nothing for the stockholders.

The following table shows the figures year by year:

YEAR	GROSS EARNINGS	OPERATING EXPENSE	INTEREST	PAID TO S. F.	S. F. PAYMENTS INVESTED AT 4% COMPOUNDED WILL EQUAL AT END OF 12TH YEAR	
1	5,000	2,500	2,500			
2	6,000	2,700	2,500	800	1,184.19	
3	7,000	2,900	2,500	1,600	2,277.29	
4	8,000	3,100	2,500	2,400	3,284.57	
5	9,000	3,300	2,500	3,200	4,210.97	
6	10,000	3,500	2,500	4,000	5,061.28	
7	11,000	3,700	2,500	4,800	5,839.92	
8	12,000	3,900	2,500	5,600	6,551.22	
9	13,000	4,100	2,500	6,400	7,199.10	
10	14,000	4,300	2,500	7,200	7,787.52	
11	15,000	4,500	2,500	3,560	3,702.58	
12	16,000	4,800	2,500	3,358	3,358.00	Total 50,456.64
					*Profit above, $5,433.60	
13	17,000	5,100	2,500	3,358	608.40	
14	18,000	5,400	2,500	3,358	1,308.40	
15	19,000	5,700	2,500	3,358	2,008.40	
16	20,000	6,000	2,500	3,358	2,708.40	
17	21,000	6,300	2,500	3,358	3,408.40	
18	22,000	6,600	2,500	3,358	4,108.40	
19	23,000	6,900	2,500	3,358	4,080.40	
20	24,000	7,200	2,500	3,358	5,508.40	
	290,000	92,500	50,000	69,712	24,467.20	

*3% on $50,000= $3,000.00
6% on 40,560= 2,433.60

6% on stock and "going value" $5,433.60

At the end of the eleventh year we have $15,000 gross earnings; $4500 operating expenses, and $2500 interest; leaving $8000 for depreciation and profit. The arrears of the sinking fund, having heretofore absorbed all the surplus earnings, can now be fully satisfied and made whole by paying into it $3560 of this $8000.

We have left $4440 profit for the stockholders. This is more than enough to pay $3000 or 6 per cent on the stock, but the stock has been deprived of a return for ten years. Three thousand dollars a year for ten years, compounding interest at 6 per cent, gives $39,-542.37 as the amount which the use of their money in the enterprise has up to this time cost the investors. They are entitled to 6 per cent on that sum, or $2372.54, in addition to 6 per cent on their original investment, $3000, making $5372.54. This sum is more than the available profit for the year by $932.54, which deficit must be added to $39,542.37, making $40,474.91 as the total deficit.

At the end of the twelfth year the earnings are still insufficient to meet operating expenses, interest, the annual contribution to the sinking fund, 6 per cent interest on the stock and 6 per cent on the capitalized deficits. The earnings are still $86 short, which, added to the deficit already incurred, give $40,560. But this is the last year that there is a deficit in the earnings.

If we capitalize the deficits already incurred, it affords a good place to pause and consider the value of the franchise. The plant has depreciated in value on the sinking fund theory $50,456.64, and is worth only $49,543.36. The profits for the year, after satisfying operating expenses and the annual sinking fund contribution, but excluding interest and dividends, amount to $7842. This is nearly 16 per cent of the value of the plant, and, according to the method at times contended for, the special franchise which had failed by $40,560 to earn a fair return on the actual money put into the business, would, on that day, be worth $81,166. This is arrived at by allowing out of net earnings six per cent on the value of the tangible assets, i. e. $2972, and then capitalizing the remaining $4870 at six per cent. The proposition is necessarily assumed to be that a reasonable man, seeking an investment, would give $81.116 for the privilege of doing this business, together with $49,543 for a depreciated plant which must be renewed at the end of another eight years at an expense of $100,000.

To go a step further: At the end of the twentieth year the value of the plant is nothing, and the net earnings are all attributable to the special franchise. They are $13,442. According to the method urged upon the courts by the taxing authorities in New York State, the special franchise would be worth $224,033. Then the plant is renewed out of the $100,000 in the sinking fund, and in the twenty-first year it is worth $100,000. This shrinks the value

of the special franchise at once to almost half of what it was the year before.

Indeed, if the privilege of doing the business is worth $81.166 at the end of the twelfth year, it would, by the same method, begin to have a value at the end of the eighth year, when the depreciated value of the plant is $69,059, and the net earnings above the operating expenses and annual sinking fund charge amount to $4742, which is $598 in excess of a 6 per cent return on the depreciated value of the property. At that time, the enterprise had failed by $47,945 to earn enough to meet the depreciation and a 6 per cent return on the $100,000 invested. But it is seriously contended that by the depreciation of the plant run for eight years at a serious loss the permission to run the business at such a loss has grown to be valuable.

The fallacy in this consists in considering the sinking fund as no longer a part of the business. The amount in the sinking fund has been taken out of the earnings and, according to the hypothesis, invested in outside securities. But this outside investment does not pay the stockholders any return. It can pay them no return until the end of the twenty-year period, because its earnings are all needed for the sinking fund. The sinking fund increases as the plant depreciates. The capital investment, after the first year, includes the original plant and also the sinking fund. The money put into the sinking fund has not been taken from the business, but has been kept in the business to renew the plant at the end of the twenty years.

The sinking fund method of taking care of depreciation requires much smaller annual contributions to the depreciation account and the accretions thereon amount to a much smaller sum during the early years of the life of the plant, whereas in the later years the accretions become a very important element, rapidly swelling the amount of the fund. Thus the works are relieved by this method in the early years from a large part of the burden which is transferred to the later and more prosperous years. It is the accretions thereon which are relied upon to compensate for the small annual payments, and to enable the business to get the advantage of these smaller payments than would be otherwise required, the earnings of the fund must be saved for the business. It is a financial device to postpone taking care of the depreciation account.

A purchaser of the hypothetical business at the end of the twelfth year would obtain a plant still effective and able to perform the

service required of it, but a plant twelve years old and with only eight years more of life. He would also acquire the securities in which the sinking fund had been invested, which, together with the depreciated plant, would equal $100,000 in value. He would also acquire a business which had cost the original investors $40,560 to establish. That is, he would acquire property which had cost $140,560. Now, according to the theory here objected to, he would also acquire with this business a special franchise worth $81,166. If the special franchise were put up for sale without any existing plant and without any existing business, the purchaser would have to spend, in addition to what he paid for the permission, not the depreciated value, but a full $100,000 to install a plant, and would have to incur losses for many years in establishing its business, although these losses might be somewhat less than those incurred by the original investors.

Is it a reasonable conclusion that such a special franchise is worth $81,166? Would a reasonable man pay for the enterprise —the plant, sinking fund, going business and franchise—$221,726? If not, then the net earnings rule as frequently applied furnishes an erroneous method.

Now, if the money which is taken out of the earnings and invested in the sinking fund had been paid to the stockholders in dividends instead, which is a procedure quite usual in case of public service corporations, it could not in any respect alter the value of the special franchise. The difference, so far as the franchise value is concerned, is a mere bookkeeping matter. If the earnings had been paid out in dividends instead of being laid aside to earn a fund to replace the plant, it ought to affect the value of the stock to its detriment, but practical experience shows that it would probably send the value of the stock up and enable the original promoters to unload it. But in either case the value of the special franchise would be the same.

A purchaser of the business in such a case would not get a sinking fund with his purchase. He would get a plant worth $49,543.36, a going business, and the privilege of operating it. He might consider the payment of a price equal to the value of the tangible assets, and the cost of the established business, $40,560, and look forward to putting another $100,000 in the business at the end of eight years. Would he be deemed a reasonable man to pay $81,166. in addition, or $171,269. in all, for the privilege of operating this franchise, for the acquired business and for the depreciated plant?

If we continue with our illustration to the end of the twenty years we find that the business can pay after the twelfth year the amount called for by the sinking fund, a 6 per cent return to the stockholders on their original investment, and on the deficit capitalized at the end of the twelfth year, through the remaining eight years of the twenty-year period, and each year have something in addition. But it does not earn enough during these years to amortize the deficit capitalized at the end of the twelfth year. The profits for the last eight years are insufficient to pay in addition to 6 per cent on the stock, the deficit of $40,560. If we conceive of the business as absolutely ending at the end of the twentieth year, the plant used up, and the business to cease, then it would be idle to talk of "going-value" attached to an enterprise which is soon to stop, and it would be improper to capitalize the deficit above mentioned. The original investors in our hypothetical case would get out of it less than they put into it, allowing 6 per cent as a fair return on the part of the investment put into the stock. The privilege of doing this business for twenty years would then be worth less than the privilege of investing in ordinary country mortgages at 6 per cent. Any arbitrary rule which gives a value to such a privilege is sheer injustice.

But if the business is conceived of as going on, there may very well be a "going-value" which is an asset belonging to the company after the twenty-year period has expired, and after the plant has been renewed by exhausting the sinking fund. If this "going-value" is recognized in valuing the franchise, the business may be considered as remunerative and the franchise can be deemed to have a value at some period before the expiration of the twenty years. If the taxing authorities were so illiberal as to allow these investors only $5\frac{1}{2}$ per cent for the capital embarked in this business, that is 5 per cent on the bonds and 6 per cent on the stock, and if, after the twelfth year, they recognize the amount in the sinking fund and capitalize the deficit as "going-value" the privilege of doing the business may properly be conceived as worth something for the thirteenth year, for its earnings exceed a return on the value of the plant, the sinking fund and the capitalized deficit.

So far in this illustration we have treated the plant as one to which no additions were made during the twenty years, but that is never likely to be the case in actual practice. A water company, if successful, must grow continually. It is always calling for new capital expenditures.

Let us assume that this hypothetical business calls for extensions and additional equipment each year, sufficient to find an investment for the amounts which we have assumed to have been invested in the sinking fund each year, including not only the annual contributions from the earnings of the original business, but also the assumed earnings of the sinking fund. Our assumption was that the sinking fund could be invested in outside securities and be made to earn 4 per cent per annum. To induce the administrators of the fund to put it into the water business, they would have to see how they could earn with it 6 per cent, which we have assumed was the fair return for the purposes of this hypothetical case, on money invested in an enterprise of this kind. So if the investment of the sinking fund is made in extensions and additions 2 per cent on the amount invested must be paid to the owners of the enterprise, as insurance against the risk, and 4 per cent must be paid into the fund. And in addition to this 6 per cent on the amount invested, the additional extensions and equipment must earn enough to meet the additional operating expenses due to the additions to the plant, and enough, besides, to satisfy a second sinking fund to offset the depreciation in the new investment.

For simplicity we will assume that the additional extensions and equipment in which the sinking fund is invested can be operated independently from the original plant and will constitute an independent system. After the end of the eleventh year, when the sinking fund to compensate for the depreciation in the original plant has been filled up from earnings, we should have invested during the remainder of the twenty-year period, the original water works which cost $100,000, the additional extensions and equipment which have cost as much as the original plant has depreciated, and the second sinking fund equal to the depreciation of the assets in which the first sinking fund is invested—altogether worth just $100,000, the amount of the original investment. At the end of the twenty years we have the additional extensions and equipment which have cost $100,000 and which, with the sinking fund created for them, are worth just $100,000, and the old original plant entirely used up. If the business done by the original plant is to go on, the original plant must be reconstructed by putting new capital to the extent of $100,000 into the enterprise. Then, at the beginning of the twenty-first year, we should have a plant which had cost $200,000, one half just reconstructed anew; one half partly depreciated; a sinking fund equal to the

depreciation of the depreciated half; a "going-value" of $40,560, and such additional value as may be attributable to the special franchise.

If the business is assumed to call for increases in the plan sufficient to absorb all of the sinking funds (which, theoretically, would serially increase almost ad infinitum,) we should have the value of the plant after the eleventh year during the remainder of the twenty-year period always exactly equal to $100,000. But we have seen that the earnings of the property invested in the sinking fund up to 6 per cent are needed for the funds themselves, to keep them whole, and as compensation for the owners because of the additional risk of such a business over a 4 per cent investment. Hence, if the additional extensions and equipment earn just 6 per cent above operating expenses and sinking fund requirements, it would be as though the money were borrowed at 6 per cent from outsiders to install the additions—which 6 per cent the additions earned. Unless these additions earned in excess of 6 per cent on the cost there would be no earnings from the sinking funds which could be attributed to the franchise. As the value of the plant all the time after the eleventh year would be exactly $100,000, the net earnings rule ought to be applied so as to allow a company a return of 6 per cent on this $100,000 before attributing earnings to the special franchise. The plant would be, according to our hypothesis, earning besides, 6 per cent on the amount invested in all the sinking funds, which would pay no income to the owners of the business as such (the 2 per cent not needed for the fund being treated as compensation for risking the fund). But if the owners are allowed a return on $100,000, when its sinking fund is invested in additions to the plant, there is no reason why they should not be allowed the same return when the fund is invested in outside enterprises. It is as much invested in the business in the one case as in the other.

Investing the sinking fund in additions to the plant and equipment is possible only when the enterprise is growing and requires additional capital expenditures. It merely defers the issuing of new securities which, if the sinking fund is used for additions, must be issued when renewals are required for the original plant, which, in our hypothetical case, was at the end of the twenty-year period.

It must be evident from the foregoing that a comparison of the earnings with the depreciated value cannot assist in the valuation of the permission to do the business. The value of the permission

to do the business does not increase because the owners of the property have lost money by the depreciation of the plant, to the point that earnings, which for a new plant would be inadequate. have become more than a fair return on an investment equal to the depreciated value of the old plant.

In an enterprise of such character we must not omit from consideration the fact that there is usually an express condition, and if not, always an implied condition, to the franchise, that the service will be rendered for a reasonable rate, and the authority granting the franchise, which is the Legislature, can regulate the rate so as to make it reasonable.

It must be evident that this hypothetical business could not have paid from the start a fair return on the capital necessarily invested at the start, and to have charged a rate which would yield such a return would either have resulted in not securing for the buisness any consumers or have unduly burdened the comparatively few consumers. But if the enterprise was for the benefit of the community and assisted in building up the community and in increasing its population and adding to the value of the real estate in the territory which it served, there is no reason in law or morals, why, after the business is built up, the investors should not be allowed to get their money back, nor why they should not be allowed a return sufficient to compensate them for the depreciation suffered by their plant, and for their renunciation in surrendering dividends during earlier years. The same considerations are involved in appraising the value of the privilege of doing business as in fixing a fair and reasonable rate. A harsh rule adopted in one class of cases will be deemed applicable in the other class of cases. The difference between the actual value of the plant and its cost of reproduction in a successful going business is a liability of the business which some day must be met. The established business has cost money to create. Both the cost of the plant and the cost of the "going-value," or at least the cost to reproduce them, should be allowed for, in appraising the value of the privilege of doing the business.

We used in our illustration a sinking fund for convenience. The bookkeeping difficulties of actually applying the sinking fund method of taking care of depreciation are so great in actual practice that it is rarely, if ever, resorted to in the case of a company serving a growing community, which is obliged to make large increases in its plant every year.

The amount of the earnings, not the disposition of them, is the important thing. Whether the amount earned above operating expenses goes to pay interest, or is set aside for depreciation, or is paid out in dividends, affects the financial stability of the enterprise and is important for the stockholders and creditors, but does not affect the value of the business or the value of the special franchise.

THE RATE OF RETURN

In a confiscation case, where a public service corporation is claiming the protection of the constitutional provisions forbidding the taking of its property without due process of law under the guise of a regulation of its rates, the rate of return is a question of law. Within certain limits, it must also be a question of law in appraising the value of the franchise. For that value must depend upon what can be earned through operating it. After the net earnings have been ascertained by deducting from gross earnings the operating expenses, taxes and annual depreciation, the question arises at what rate the net earnings shall be capitalized in order to obtain the total value of the entire property, tangible and intangible, employed in the production of the net earnings. There is a disposition shown to adopt 6 per cent, the legal rate of interest, in all cases. This is grossly unfair to the more hazardous enterprises, like a country water company. It is largely due, we believe, to the suggestion of the court in the Jamaica Water Supply Company case (196 N. Y., 39, 58), where it was said:

> The court below might properly assume, as a matter of general knowledge in the business community, that a prospective return of at least the legal rate of interest, which is 6 per cent in this State, is requisite to induce investors to embark their money in enterprises of such a nature as that undertaken by this corporation.

But in that case it was the defendants who appealed, and the corporation was seeking to sustain a decision, which had capitalized its net earnings at 6 per cent. The Court was not called upon to decide that 6 per cent was sufficient.

In Consolidated Gas Co. v. The City of New York, 157 Fed. Rep., 849, the Court, in passing on the question of the rate of return, said (p. 871):

> An interest in the gas business of this city is as nearly a conservative investment as any private manufacturing enterprise can furnish, and although each case depends upon its special facts, there is, after problem conditions are ascertained,

one question that can always be asked: What would that prudent man acquainted with business (so familiar to the readers of legal literature) do regarding such an investment, if it were offered to him? I think he would take it, not with enthusiasm, but as fairly safe local property, promising a rate of return sufficiently above the local mortgage market to compensate for the additional and non-insurable hazard. He would expect and have just and reasonable right to expect a return of 6 per cent, not because that happens to be the interest rate by law established in the State of New York, but because it is the return ordinarily sought and obtained on investments of that degree of safety in the City of New York.

Again, in the case of Wilcox v. Consolidated Gas Co., 212 U. S., 19, the Court said, referring to the Company's business (pp. 48, 49):

There is no particular rate of compensation which must in all cases and in all parts of the country be regarded as sufficient for capital invested in business enterprises. Such compensation must depend greatly upon circumstancess and locality; among other things the amount of risk in the business is a most important factor as well as the locality where the business is conducted and the rate expected and usually realized there upon investments of a somewhat similar nature with regard to the risk attending them. . . . The less risk the less right to any unusual returns upon the investments. One who invests his money in a business of a somewhat hazardous character is very properly held to have the right to a larger return without legislative interference than can be obtained from an investment in government bonds or other perfectly safe security. The man that invested in gas stock in 1823 had a right to look for and obtain if possible a much greater rate upon his investment than he who invested in such property in the City of New York years after the risk and danger involved had been almost entirely eliminated.

In an investment in a gas company such as complainant's the risk is reduced almost to a minimum. . . .

An interest in such a business is as near a safe and secure investment as can be imagined with regard to any private manufacturing business, although it is recognized at the same time that there is a possible element of risk, even in such a business. The court below regarded it as the most favorably situated business in America, and added that all gas business is inherently subject to many of the vicissitudes of manufacturing. Under the circumstances, the court held that a rate which would permit a return of 6 per cent would be enough to avoid the charge of confiscation, and for the reason that a return of such an amount was the return ordinarily sought and obtained on investments of that degree of safety in the City of New York.

Taking all facts into consideration, we concur with the court below on this question, and think complainant is entitled to 6 per cent on the fair value of its property devoted to the public use.

Now, if the Consolidated Gas Company, which has been going so long that its original franchises have long since expired, and is operating in one of the most populous districts in the world, is

entitled to 6 per cent, what is a country water company entitled to? Surely it is entitled to more than the prevailing rate of interest for good mortgages in the territory served by it. Its investors are like the man who invested in gas stock in 1823, referred to by Judge Peckham.

In Trustees of Saratoga Springs v. The Saratoga Gas, Electric Light and Power Company, 191 N. Y., 123, the Court said (p. 151):

> One can hardly be expected to invest capital in an enterprise involving risk for the same return that he could receive from an investment in safe securities.

In the same case in the Appellate Division, 122 App. Div., 203, the Court said (p. 219):

> Such a corporation, however, is entitled to a fair return upon the actual value of its property that it is devoting to the public use, after paying all expenses and liabilities reasonably charged against the same. What is deemed a fair return must depend ultimately upon the judgment of the court. In 1886 the committee of the Senate of the State recommended for a gas company in New York a return not exceeding 10 per cent upon its investment. The New York Mutual Gas Light Company, by its charter, is permitted to earn dividends to the extent of 10 per cent. The Senate committee of 1905 assumed a return of 8 per cent as proper and the Gas Commission in 1906 found that 8 per cent was a reasonable return upon the actual value of complainant's property used in gas manufacture. The Railroad Law of the State (Laws of 1890, Chap. 565, Sec. 38, as amended by Laws of 1901, Chap. 639) permits the Legislature to reduce the rate of freight or fare, but the same shall not without the consent of the corporation be so reduced as to produce less than 10 per cent per annum on the capital actually expended. An investor may loan his money upon sure security, and is allowed by law to charge 6 per cent for the loan. The investment in a gas and electric light company, however, is not secured as a loan upon abundant security. There is in it a greater risk of loss, and upon all economic principles the investment should for that reason be entitled to a greater rate of return than an investment loan upon approved security. If the court should allow to these investors only the same or a less return than is obtained for a loan upon approved security, no capital would henceforth be advanced for these enterprises, and the public would either be deprived of their advantages or the municipality would be compelled to build for itself. Both upon principle and necessity then, a fair return upon the value of the property actually used is such a return as shall be fair compensation for the risk assumed by the investor in permitting his money to remain in such an enterprise.

The question of the rate of return has usually come up where corporations are seeking the protection of the constitution, and claim that the legislature, or somebody authorized by it, has fixed the rates which it can charge at a figure which is confiscatory. But that is not the case where a Special Franchise is being ap-

praised. The question then is to determine the rate of return which would induce free capital to invest in a similar enterprise.

A Water Company is entitled to have considered all of the disadvantages under which it labors. It is subject to many possibilities for disaster which do not menace enterprises not operating special franchises. It is subject to interference on the part of the public authorities in many ways. It may have contractual relations with municipal corporations. Every one knows how costly it is to collect money due from the public and how difficult business negotiations are when carried on through public officers. The Company's rates are subject to revision by the public within the limits imposed by the Constitution. Rates are likely to be ruthlessly dealt with. Its watershed is likely to be raided by competitors seeking water. It may have to meet municipal competition.

Another obvious drawback to an enterprise of this kind is the impossibility of withdrawing after embarkation. When a large sum of money has been invested in pipes in the streets and in a pumping station, unless the owners are prepared to lose everything they have put in, they must continue. And continuing in a growing community means not only leaving in the business what is already there, but finding new capital to meet the increased demands of the service. It often means a long period during which vast sums are swallowed up and little or nothing taken out.

The net earnings are not all distributable to stockholders. No prudently managed corporation can ever pay out in interest and dividends all of its net income.

In, In re City of Brooklyn, 143 N. Y., 596, known as the Long Island Water Supply Co. case, the Court of Appeals held that, if the franchise were exclusive, the award found by the commissioners would be confiscatory, but held that franchise to be not exclusive. In that case the land, pipes and improvements of the Company were worth $370,000, the gross earnings were $84,000 and the expenses $20,000. After attributing to the tangible assets, including the land, earnings of 6 per cent, there remained a balance of over $41,000 to be attributed to intangible rights. The whole award was $570,000—that is to say, $200,000 was given for the going concern value, the contracts of the Company and the franchise—all the intangible rights of the corporation. If this figure was arrived at by the "net earnings rule," it was capitalizing the net earnings at 20 per cent, after attributing 6 per cent to the tangible assets.

In the case of Shepard v. Northern Pacific R. Co., decided on April 8, 1911, in the United States Circuit Court for the District of Minnesota (184 Fed. Rep., 765), Judge Sanborn, referring to the rate of return to be allowed on the undepreciated reproductive cost plus allowances for solidification and adaptation of the roads, in a case where the Court held that the rates prescribed by the Minnesota Legislature and the orders of the Railroad and Warehouse Commission were unreasonably low, unjust and confiscatory, said (p. 815):

Complaint is made that the master finds that the companies are entitled to a net return of 7 per cent per annum upon the respective values of their properties devoted to this public use. The character of the business in which an investment is made, the locality in which it is placed, the returns secured in that locality from other investments of a similar nature, the uniformity and certainty of the return, and the risks to which the principal and the income from it are subjected condition the measure of a fair return upon capital invested. An investment in a bank, in a factory, in a mercantile, manufacturing, or agricultural business, is substantially free from regulation by the government and exempt from any duty to the public, except that of paying taxes. If the business in which such an investment is made is unprofitable its owners may promptly discontinue its operation until more prosperous days come and then return to their undertaking. An investment in a railroad which operates in many states is subject to the regulation of its business by many governments. Its owners owe the duty to the governments and to the public to operate their railroad continually in days when its operation is unprofitable as well as when it is remunerative, a duty they must discharge under the penalty of the forfeiture of their property if they fail. In view of these facts, they ought to be permitted to receive a return large enough to enable them to accumulate in prosperous days a surplus sufficient to enable them to protect their property in days of disaster and to make their average return through days of prosperity and of adversity fair and just. The lands in Minnesota through which these railroads extend are fertile and productive. The cities, villages and towns they reach are rapidly increasing in population and wealth, and the people they serve are thriving and successful. The evidence satisfies that the railroads are maintained in excellent condition, that they are efficiently and on the whole economically managed and operated, and are rendering commendable service. Justice to the thriving people they serve does not require that the owners of these railroad properties should be deprived of a fair return upon their values. To deprive them of such a return would prevent advances and tend to compel reductions in the wages and salaries of their employes, would tend to prevent the extension of their lines into portions of the state where the development and accommodation that railroad service assures would be welcome and may be needed, to deteriorate the character of the service they render, and to retard the general prosperity. The legal rate of interest on a debt in Minnesota, in the absence of contract, is 6 per cent, and by contract it may be 10 per cent, per annum. Rev. Laws Minn., 1905, sec. 2733. Rational investments in agricultural, manufacturing, mercantile and other industrial pursuits, and even well-secured loans, yield returns in Minne-

sota corresponding with these lawful rates. Investments in railroads and the returns thereon are at the risk of failures and partial failures of crops, of the disasters, delays and expenses of unusual storms, snow and cold, of the great financial disasters which occasionally prevent or delay the movement of traffic, and of the burden of continuous operation whether profitable or unremunerative. It is an axiom in economics that the greater the risk the greater must the return be upon invested capital, and the conclusion is irresistible that a net return of 7 per cent per annum upon the respective values of the properties of these companies in Minnesota devoted to transportation is not more than the fair return to which they are entitled under the Constitution of the United States.

The bankers have developed facilities for investing to the point where every man may invest his money whether he has a large amount or a small amount in the place that suits him in any part of the civilized world.

The real interest of the people of this country is to attract the capital of the world, so that our enterprises may get the benefit of a low interest rate. We shall accomplish this when we succeed in making it clearly understood that the governmental machinery, which we set up in this country to exact compliance with the condition attached to every public service franchise that the service be rendered at a reasonable rate, will deal fairly with capital.

A few flagrant acts of injustice may have a far-reaching effect and can cause an immense increase in the cost to the country for the new capital required to develop its public service enterprises.

The increased interest which railroads have to pay today, in comparison with what was paid for new capital a few years ago, certainly amounts to twenty-five per cent and perhaps to forty-five per cent. This is probably not due entirely to the action of public service commissions, but it may be assumed that the uncertainty as to the rules which may be adopted and the far-reaching character of the doctrine laid down in the Knoxville Water Works case (212 U. S. 1), has had its influence on the present situation.

The loss caused to the community by highwaymen is not the amount the highwaymen succeed in stealing from particular individuals, but the risk and impediment which their occasional depredations cause to all traffic. And so the benefit to the community at the expense of investors through a few isolated acts of injustice may be off set a thousand fold by the disadvantage to the entire country of having to pay a larger interest rate for new and free capital.

It is for the interest of public service corporations and of the public equally to shorten the period of uncertainty.

We must all recognize that the public from now on proposes to require an observance of the condition attached to special franchises—that the service be rendered at a reasonable rate.

There is a twilight zone between what is fair and reasonable under the circumstances, and what is so unfair and unreasonable as to amount to a violation of the constitutional provision against taking property without due process of law.

We can expect really fair treatment from public service commissions only when public opinion is enlisted in our favor and that period we cannot expect to reach until the public is convinced that our accounts are honestly kept and that the methods of valuation adopted are fair.

We should all of us assist in leading public service commissions and the public generally to a right understanding of the questions involved and welcome public supervision of our accounts and operations.

The advantages of public supervision must in the end far outweigh the disadvantages. If water works are protected against interference with their supplies and against the paralleling of their distribution systems and against breaches of trust on the part of their officers, they are relieved from far more menacing dangers than those involved by supervisionly public commissions.

When investors become satisfied that a wise public policy will obtain with respect to the regulation of water companies, capital should be available for such enterprises at as cheap a rate as for any public service and the rate of return which the consumers are called upon to pay for profit on the capital invested correspondingly reduced.

DISCUSSION

Mr. C. D. SeCheverell: The paper seems to be antagonistic to the methods employed by the Tax Commission of the State of New York in assessing for taxation water works franchises. In order to get the full benefit from the paper and appreciate the stand that Mr. Baldwin takes, we should know what the regulations are that this Tax Commission has laid down. Mr. Baldwin is suggesting methods of arriving at the value of franchises which it seems the Tax Commission has ignored.

Mr. Morris Sherrerd: There is a tendency at the present time by expert accountants to evolve systems of accounting, and to

precipitate them upon municipalities, in such a manner as sometimes to militate against the proper adjustment of rates. In other words, you may have a five million dollar issue of bonds with a million dollar sinking fund appearing on both sides of the ledger, and there may seemingly be a deficit up to the time that the five million dollars is paid into the sinking fund, when there at once appears a surplus of five million dollars. The instant the five million dollars is paid into the sinking fund, the present generation, if that method of fixing rates is to be pursued, loses the advantage of the funds that are in the sinking fund. Debits of payment to the sinking fund are in addition to the amount charged off for depreciation. It is practically putting depreciation in twice, for a municipal water department starts off in a different way from a private water company which starts off with paid in capital. The municipality starts off with nothing but bonds; and if you put them into the sinking fund and pay off the bonds when they are due, and if you also put them into your depreciation account to the amount necessary to rebuild your plant, you are getting the thing back twice. The speaker believes this to be a questionable procedure. The matter is perhaps more serious than merely affecting the rates in the water department. It seems to be the root of a good deal of evil in the way of watered stock and over-capitalization; but that is their method of treating the sinking fund. For instance, with a big corporation having bonds outstanding that are redeemable after ten years, or at the will of the Board of Directors, suppose half a dozen directors get their heads together and say, "We have two million dollars in the sinking fund applicable to paying off these bonds," and then they proceed to do what is called "cutting the melon," all brought about by this system of accounting which seems to the speaker to be on a wrong basis.

Mr. Wm. H. Winslow (by letter): The author apparently assumes that any element of value in a water works property, due to the existence of net earnings in excess of a sum equal to a "fair return" on the capital invested, is franchise value.

Judged by the context, the expression "fair return" is used, not in the sense of a rate of return, any increase of which would produce an unfair or excessive return, but as meaning, rather, a minimum fair return, or one barely sufficient to maintain the value of the property on a par with its cost. If we assume that the expression is used in the former sense, then any value based on earnings in excess of such a maximum fair return could not be described as franchise value, using the word franchise as meaning merely "the

permission to use the streets," for the right to the use of the streets carries with it no right to excessive earnings. If, however, such earnings were due to contractual rates embodied in the franchise, the resulting value might properly be called "contract value." Using the term "fair return" as meaning merely one which if increased would give to the property a value in excess of its cost, without, however, producing an excessive return, is such a value properly describable as franchise value?

As the value of any industrial property is the present worth of future expected net earnings, practically the entire value depends on the right to realize such earnings, as, deprived of this right, the only value remaining would be the salvage value of the property. The fact that practically the entire value of a property depends on its right to do business does not, however, mean that any certain part of that value can be properly labelled "franchise value."

If we assume that a net return of 7 per cent will just keep the value of a water works property on a par with its cost and that only half of that rate is being earned, then the value will probably be about 50 per cent of cost. This does not mean, however, that the "plant" has a positive value equal to its cost, and the franchise, a negative value equal to half that sum. The franchise may be worth nothing, but it cannot be worth less than nothing, and the essential fact is that the value of the property as a whole rises or falls as the net earnings increase or diminish.

It is unfortunate that the author of this very able paper did not define the term "Special Water Works Franchise," because, if it is used in the sense of a contract for supplying water at fixed rates, as well as the right to occupy the streets, the question of value becomes quite different from what it is when only the latter is mean.

Mr. A. S. Malcomson (by letter): The element of "good-will," discussed in Mr. Baldwin's paper on the "Valuation of Water Works Special Franchises," may at times have existence and even material value in the case of a monopoly, notwithstanding the fact that the courts seem to be more or less unanimous in refusing to consider it.

The quotations from the Kennebec Water District *v.* Waterville Case, to the effect that "good-will" is "Nothing more than the probability that old customers will resort to the old place" and that "This phrase is inappropriate where there can be no choice," are in point. This does not seem to be broad enough to cover the facts,

as customers always have the choice of not resorting to any place at all, whether there be monopoly or not; and the statement that "(water) customers are retained by compulsion, not by their voluntary choice," in the case of Bristol *v.* Bristol Water Works, may be correct in some or even many cases, but by no means all Water Companies are so situated.

Perhaps the choice of not taking water at all is more apt to be exercised in rural districts where private sources are better available, but are not monopolies most prevalent in such conditions? Or looking at the subject in another light, it might perhaps be said that there is no such thing as a water company which has a monopoly, as there are always many outside sources from which water can be obtained, and this recourse is often had to a greater or less extent where the street supply is dirty, odorous, or even suspicionable.

The giving of a satisfactory service, which unquestionably generates "good-will," is often if not always a case of intelligent and diplomatic management, and frequently is less expensive to the Company (or City) in actual outlay than would be the case where dissatisfaction is prevalent. Satisfactory service also creates additional revenue, as well as insures the continuance of the same, much of which may be lost under a new management less alive to its value.

As an illustration we might imagine a water company established, say twenty years, in a growing city and giving good and efficient service. It is a monopoly but it has the good-will of the people because they have been well and fairly treated. The business, we will say, has been established at the cost of a certain amount of money—the "going value," but owing to the very efficient and diplomatic manager secured by the foresight of the directors, at no greater cost than many of less ability, there is a great deal of "good-will" towards the company which has cost nothing in dollars and cents, but grew out of the fact that the ones interested in the enterprise were thoroughly capable men.

Then comes the change. For any one of a number of reasons the city buys out the company. The City Fathers relieve the manager of some of his powers, and adopt some short-sighted policy of management which brings in a few consumers but loses many more. The carrying out of this policy has cost some money, which has increased the "going value" cost, but the "good-will" of the company has depreciated.

Good-will has somewhat of the personal element in its composition, but it is in large measure a lasting attribute of any business, even in the face of a direct reversal of policy. The confidence of a community is hard to secure, but sometimes much harder to lose. To arrive at the money value of "good-will" may require an out and out estimate in the case of a monopoly, as it is, in the sense outlined above, intangible of the intangibles, but to deny its existence is but to side-step the facts. If there be good-will where there is competition, its value might presumably be based on the relative volume of business of the two competitors. Is it reasonable to assume that if the smaller competitor discontinues, the good-will of the larger one will thereby lose its value and become at once but an empty shell?

RATES AND RATE MAKING UNDER THE WISCONSIN PUBLIC UTILITY LAW

*By Halford Erickson

We hear a great deal today about government regulation, not only of public utilities, but of other enterprises where monopolistic conditions prevail, and which are affected by public interest. Such regulation is not only advocated by many, but in many respects it is actually put into effect. The national government, for instance, has enacted pure food laws, anti-trust laws, the interstate commerce law, banking and corporation laws, and other similar legislation. Many states have also enacted laws of this kind together with laws for the regulation of the rates, services and other conditions of the intrastate business of all kinds of public utilities. The enforcement of these laws are usually entrusted to special bureaus or commissions which are created for this purpose and provided with the necessary power to that end.

Such regulation, while it operates as a restraint upon the actions of individuals and corporations, is not intended to unduly interfere with the management and operation of the industries affected. It is based upon the principles that public interests are superior to private interests, and that no one shall use his own to the detriment of the many. Public utilities especially are so affected by public interest, that public policy requires that they should furnish adequate service at reasonable rates without unjust discrimination. This is required by law and constitutes the main principles upon which such regulation is based.

No part of the regulation of public utilities is of greater importance than that which is concerned with the rates charged for the services they render. These rates measure the income of the utilities as well as the sacrifices which their customers must make in order to be served. Rates that are unreasonably high or unjustly discriminatory are contrary to public policy. Through such rates money or wealth may be unjustly transferred from some classes of persons to other classes of persons, and from some localities to other

* (Member Wisconsin Railroad Commission).

localities. Rates that are too low are also inimical to public interests and this for the reason that they usually result in poor service as well as in the lack of necessary extensions of the same. Unreasonably low rates may even result in entirely depriving a community of such services.

My purpose here is to explain the work involved, the facts that are needed and the methods employed in making rates for water works under the Public Utility Law in Wisconsin.

The law provides that the rates must be reasonable, both absolutely and relatively. The courts and commission generally hold that, under normal conditions, the rates, when taken as a whole, should be high enough to yield reasonable amounts for operating expenses including depreciation and interest and profit on the fair value of the property that is used and useful in serving the public. They also hold that each department of the service and each class of customers in each of these departments should bear their just proportion of these outlays. In other words, the cost of the service as thus stated is made the legal basis for rates. Properly analyzed and understood, the cost of the service basis for rates is also in line with economic principles and public policy.

To determine what is the reasonable total amount a public utility should receive for its services, and to properly distribute this cost, not only over the different departments of the service, but between the various classes of consumers in each of these departments, is an exceedingly difficult task. It requires a complete appraisal of the property involved, as well as full information concerning all the factors which enter into the total cost of the service and as to how this cost should be apportioned between those by whom it must be borne.

The property of a utility usually covers the labor, material and other factors including overhead expenses that enter into the physical plant up to the point where it is ready for operation. Similarly it may also cover the cost of the business itself or its going value. The evidence as to what is the fair value of this property and of the business is mostly obtained from two lines of inquiry, and one of these lines is represented by efforts to find the original cost of both the plant and of its business. The evidence of this cost is obtained from the records of the plant, its design and the conditions generally which prevailed at the time it was constructed and its business developed. The other line of investigation consists of determining what it would cost to reproduce the plant and its business at the

time of its appraisal. This requires complete inventories and statements of every element that make up these costs as well as the prices at which these elements can be had and made a part of a completed plant with a going business.

The original cost and the cost of reproduction new of the physical property of the plant, as thus determined, is in each case reduced by the amount of the depreciation that has taken place in the property up to the time of the appraisal.

The amounts obtained by these reductions represent the so-called present cost values of the physical property. The original cost of the physical property less its depreciation is then increased by the original cost of the business alone. In the same way the cost of reproduction new of this property less its depreciation is increased by the cost of reproducing the business alone. The two cost values of the plant and its business as thus obtained, even when they are some way apart, usually furnish the best evidence of the service and upon which the returns for interest and profit should be based.

The next step consists of determining the total cost of the service or the absolute amounts to which the utilities are entitled for operating expenses, including depreciation and returns for interest and profit. These amounts are determined upon from a close study and analysis of all the facts obtainable with respect to the operating costs and conditions of the plant, the probable length of the useful life of its property, the conditions and terms upon which capital can be had and other factors of this character.

In order to obtain cost bases for specific rates that are relatively fair, it is necessary to apportion the total expenses in such a manner that, in connection with proper operating and traffic data, they can be made to show proper costs per unit. The first apportionment in this respect is between the factors upon which these expenses depend or between consumer, demand and output costs. These three classes of costs are then divided between the different departments of the service. The respective consumer, demand and output costs for each department are then distributed over the various classes of consumers in the department. The proper unit costs for each class of consumers are then determined and these unit costs, especially under normal conditions, usually constitute the basis upon which rates that are equitable and just to all concerned can best be determined.

Public interest requires that the rates should be high enough to cover the cost of adequate service, and to bring the necessary capital

and the best managing ability into the public utility field. The services of public utilities bear a close relation to the welfare and comforts of the community. Water works, for instance, are vitally connected with the health and with sanitary conditions. The water delivered must be pure so as to be safe for domestic and industrial uses. The plant must be in position to furnish adequate fire protection. In fact, it must be able to meet all legitimate and proper demands that are made upon it.

Practically every water-supply plant has two almost entirely distinct functions. The service which it renders has two very different purposes, first, the supply of large quantities of water, usually under high pressure, for relatively short periods of time for protection against fire, and second, the supplying of water under moderate pressure at all times for commercial and industrial purposes. To a limited extent other utilities supply different classes of service. Electric plants, for example, will supply both light and power, and in their lighting business will be included street lighting and general commercial lighting. But the difference between the two classes of service supplied is not as great as in the case of a water utility. The relative importance of these two branches of service is dependent largely upon the local conditions which are met with. In small cities where a relatively pure supply of water can be obtained through shallow wells, the most important function of a public water-supply system is to furnish fire protection. In larger cities it becomes of great importance that there be a public supply of water for general purposes because of the difficulty of obtaining pure water from private sources of supply.

The fact that in many cases the furnishing of water for fire protection is the most important of the two general purposes for which water-supply systems exist seems to have been very generally overlooked by many of those who formulated the rate schedules which have been in use. Particularly does this seem to have been true in the case of municipally owned plants. Very frequently is it the case that municipally owned water plants are supported almost entirely by the revenues from commercial and industrial service. Even with privately owned plants there seems to be a tendency toward this condition, probably due to the fact that many of these plants have been unable to secure franchises which required the municipality to pay the full cost of the fire service.

The rates which the water works utilities have themselves put into effect for these services do not often seem to come within the

rules and principles which have thus been laid down. That this is the case may readily be seen by examining their rate schedules. In most places the charge to the municipality is fixed at so much per hydrant regardless of the cost to the utility of this service and of the distance between these hydrants. There are also places where this charge is placed at so much per mile of mains, without reference to their size and to many other conditions that affect the cost.

For street sprinkling one city pays $6 per wagon per month; another $6 per wagon for the season. In other cases again, the charges are based at so much per front foot of abutting property, or per mile of street per season, or a lump sum per year. In some few instances the water is actually metered and charged for on that basis.

It is impracticable to attempt to review all the types of flat-rate schedules in use in this state, but in a general way it may be said that charges under flat-rate schedules relate, 1. to the character of the premises supplied; 2. to the number of fixtures from which water is drawn, and, 3. to other elements such as the number of rooms or persons supplied. In cities where the water-supply business has developed to any extent the flat-rate schedules have proven unwieldy and poorly adapted to uses not easily classified, and the result has been the growth of special rates which are very often discriminatory.

But even without the injection of special rates, flat-rate schedules are inevitably discriminatory. The theory of flat-rate schedules is apparently this: that the normal demand on the system, and the normal amount of water used depend on the number of openings or on one or more of the other conditions given above. A little thought will disclose that this is not the case and that rate schedules built up on such bases are far from what they should be.

A consumer, for instance, who is careless and wasteful uses more than a normal and reasonable amount, thus adding to the expense incurred by the utility, which, in turn, must shift the burden to the frugal consumer. A plant supplying water through a kitchen faucet to a 5-room residence sells, *not* the maximum amount that may be drawn, but a quantity estimated to be reasonable. When the use becomes more than normal and reasonable the number and nature of fixtures is no longer an index and it becomes necessary to introduce a certain and definite system of measurement.

When the flat-rate system fails, as it usually does in the long run, it is usually succeeded by the meter system of charging. That this

change results in many improvements in the rate schedules needs no argument. This is especially true when the additional cost, in the way of fixed charges and other expenses incurred thereby, does not exceed the savings effected in the use of water through meters. Instances are known where the decreased waste that has resulted from the installation of meters and meter rates has been great enough to enable an overtaxed water-works plant to furnish adequate service or the needed pressure.

The meter rates thus put in effect, however, are not always the result of careful or scientific study. Often they are copied bodily from those in use elsewhere without reference to local conditions. There are today many cities whose regressive schedules of meter rates are almost identical although the cost of the service is greater in some of these places than in others. Instances of regression have been found where one consumer, for the same payment, could use $2\frac{1}{2}$ times as much water as his neighbor, while intermediate consumers paid less than either.

The commonest type of meter schedules in use provide a decreasing charge per unit for increasing quantities of water used. Sometimes these rates are supplemented by a minimum charge which in some cases vary with the size of the meter and in other cases not. Many of these schedules are mostly so adjusted that at many points they result in a higher total cost for a smaller than for a larger quantity of water.

Rate schedules of this sort are as a rule unjustly discriminatory and unreasonable in other respects. They have, however, been permitted to remain in effect not only for water works, but for other utilities until they have, in part, become responsible for the existing demand for regulation. The best methods of correcting such inequalities would seem to be by providing rates that bear closer relations to costs.

Having determined the fair value of the property and of the business, it is essential that we know what part of these values should be apportioned to each of the two main branches of service which most water utilities furnish. Separate plants to furnish fire protection and general service would differ in many respects. For fire protection the system must generally be so designed that a great amount of water, under high pressure, can be furnished at any point to be protected, the amount of water which can be delivered in a given time, depending upon the nature of the risks in the area affected. There must be powerful pumping machinery, a plentiful

supply of water, large mains capable of withstanding pressure and a sufficient number of hydrants. If the systems were to serve the commercial and industrial consumers only, a somewhat different set of requirements would be found. The supply of water must be pure, it need be delivered only under moderate pressure and the distribution system need not usually be designed to furnish a large amount of water at any point to which the system extends. When, as is usually the case, one water supply system serves both purposes the system must be able to meet the requirements of both classes of service. There are certain economies resulting from the use of a combination system, economies both in construction and operation.

Because of the fact that water plants serve two widely different purposes, which makes the investment somewhat higher than it would be for either service separately, it becomes necessary to apportion the property so that each branch can be assessed with its fair share of interest, profits and depreciation. There is no unanimity of opinion as to what the basis for apportionment should be. Some regard the general service furnished by the utility as of first importance and contend that the fire service should pay interest only on the excess investment above what would be required in a plant to furnish general service only. In other cases there is no question but that in many cases the plant was installed mainly to furnish fire protection and that the general service may be secondary, even though it may be well developed. In such cases the question arises as to whether the commercial and industrial service should return interest on merely the excess investment required for that service. Generally speaking, however, it seems to be true that both classes of service should be considered as coördinate and that the apportionment should be made in such a way that this condition will be recognized. Instead of charging one class of service merely with the excess investment, the fairer method seems to be to consider that both classes of service need a public water-supply system and that each should bear the burden of interest, depreciation and profits, according to an apportionment of the existing plant based upon the relative costs of entirely separate systems. This, in general, is the method which our Commission follows, and it seems to be the most equitable of the bases so far employed. It discloses the fact that fire protection alone is often responsible for from 40 per cent to 60 per cent of the cost of the plant, depending upon the size of the plant and other local conditions.

The operating expenses proper, or, the other costs than the fixed

charges just mentioned, are also for the most part common to the two branches of the service, and must be apportioned between them on bases that are more or less arbitrary. Among the reasons for this are, that the service for both branches is furnished by the same utility; that the water is taken from the same supply and pumped by the same pumps and power, and that it is delivered in the same mains, etc.

What these methods of apportioning the operating expenses should be must depend largely upon the nature of the different expense items and the elements which cause them to be present. It is at once evident that not all of the expenses of a water-supply system are affected by the same elements. For example, not all of the expenses are related to the amount of water pumped. A decrease of a given amount in pumpage will not lessen the expenses by a corresponding amount. The expenses incident to keeping the distribution system in repair are related only very indirectly to the number of gallons of water passing through the system. They depend rather upon the extent and capacity of the distribution system. The cost of reading meters and keeping the consumers' ledgers is related more directly to the number of consumers than to the amount of water they use. Not even all of the costs of pumping water are directly proportional to the volume of water pumped. To illustrate this, let us assume a case where a system is used for fire protection only. Aside from such leakage as there may be, water will be delivered to the mains only in the relatively infrequent instances when it is actually used in case of fire. Nevertheless, fires must be kept up so that water can be pumped at any time. Boiler room and pump laborers must be on duty. Boilers, pumps and buildings must be maintained. A considerable part of the pumping expenses are expenses which are incurred by keeping the station in readiness to serve. For it is as a rule impractical to pump at a uniform rate throughout the day or the year, even when a standpipe is used. While the demands upon the plant vary greatly from time to time, it must constantly stand ready to meet the greatest demand made upon it. To do this requires something more in the way of operating expenses than would otherwise be necessary. The standby costs resulting from such conditions are present in practically every case and constitute no inconsiderable part of the total cost of pumping.

The operating expenses of a water utility, then, may be said to be influenced by three principal elements: the demand which the plant

must meet, or the capacity which is required, the amount of water pumped, or the output, and the number of consumers supplied. For the sake of convenience these may be referred to as capacity, output and consumer costs. These costs differ as to their nature and this fact must be considered in efforts to so distribute them that each branch of the service and each customer or class of customers are made to bear their just share of the total cost.

It will be evident that only a small proportion of those expenses which vary with the amount of water pumped should be borne by the fire protection service. Very little water is actually used by this device, in some cases not over 1 or 2 per cent of the total amount pumped. The share of the consumer expenses that should be charged to the fire service is also small, consisting of little more than cost of keeping up the hydrants. The fire service makes large demands upon the system, and the expenses incident thereto are mostly dependent upon the extent and nature of these demands, and upon the capacity required to meet them. In fact this cost is largely made up of fixed charges and standby expenses.

The first step, therefore, in separating the cost of fire protection from the cost of general service, must be to divide the operating expenses among the various classes of capacity, output and consumer expenses, according to the elements which influence each expense item. It will be at once apparent that no arbitrary rule for apportioning expenses can be laid down which will cover all cases. Some of the expenses, such as the cost of fuel, are governed both by the plant capacity, which must be kept in readiness to meet possible demands, and by the actual pumpage. The proportion of fuel costs which should be considered as a capacity expense, as distinct from expenses which vary with the output, must be determined by a study of the operating conditions of the plant under consideration. Some of the expenses are influenced by two or more of the elements which have been mentioned, others are entirely due to one element. For an average or typical plant of the kind the capacity expense would amount to about 38 per cent, the consumer expense to about 18 per cent, and the output expense to about 44 per cent of the total operating expenses.

In order to obtain the respective operating costs for fire protection and for the general service, it thus becomes necessary to introduce some further apportionments. In this work care must be taken that the bases used bear a close relation to the class of expenses to be apportioned. Output expenses should be apportioned upon

the basis of the amount of water pumped for the different branches of service. Capacity or demand expenses should be apportioned upon the basis of the respective demands of the two classes of service, with the exception, perhaps, of such items as the cost of maintaining mains, where the expense may be apportioned on the same basis as is used to apportion the investment in the distribution system. Consumer expenses should be allotted on the basis of the number of consumers unless treated as capacity costs.

This introduces the necessity of measuring the respective demands of the fire service and of the general service and of ascertaining, as closely as possible, the pumpage for each division. In many cases the franchises, under which water utilities have been operating, contain definite requirements as to the amount of water or number of fire streams which the plant must be able to deliver for fire protection under stated conditions. The measurement of the maximum pumpage rate for domestic service is more difficult. Water plants often fail to keep records of the daily output, and of the variation in the rates of pumpage during the day. A careful study of all elements affecting the use of water for domestic and industrial purposes is therefore necessary in most cases. One shortcoming of these methods is, that they do not show for any given time the maximum combined demand of the two branches of the service, which may be somewhat different from the separate demands. In most cases the separate peaks will therefore have to be used as a basis for apportioning capacity expenses. When full pumpage records are kept by the utilities, however, it is usually possible to approximate quite closely the amount of water pumped for fire and for general purposes, and the relation between these quantities furnishes the basis for apportioning output expenses between the two branches.

To further illustrate this point, it may be mentioned that for an average plant the fire demand may be 1200 gallons per minute while the demand for domestic and industrial service may reach 1000 gallons per minute. On the basis of these demands 54.5 per cent of the capacity part of the operating expenses should be apportioned to fire and 45.5 per cent to general service.

The amount of water used for fire purposes is comparatively small. It seldom amounts to more than from 1 per cent to 2 per cent of the total pumpage. The fire service should therefore not be charged with more than this proportion of the output expenses. Being in reality only one customer, its consumer charges, even when the upkeep of hydrants, etc., is included therein, are also small.

The taxes, depreciation and interest and profit for the general service, in order to obtain proper bases for rates, must also be apportioned between capacity, output and consumer costs. These apportionments may be safely based on the same relations as those which obtain for the operating expenses alone. That is, the fixed costs may in this case be treated as overhead items. For the fire service such apportionments of the fixed charges are not often necessary as the fire service charge can be levied in a lump sum.

When the reasonable total cost of the service has thus been ascertained; when this total cost has been allocated as between the capacity output and consumer costs, and when each of these three classes of costs have in turn been apportioned between each of the two branches of the service, or between fire and general service, the task still remains of so distributing these capacity, output and consumer expenses for each branch over the customers therein that each such customer is made to contribute his just share of the total revenues of the utility. This, the last step in the operations, is usually carried out through rate schedules built up from the unit costs obtained in preceding calculations.

To formulate rate schedules for the fire service is as a rule a simpler task than is the case for the general service. When the municipality bears the entire cost there is in fact only one customer to deal with, and this cost can therefore be assessed in one lump sum instead of through a complicated schedule in which the demand and output costs are provided for by separate charges. When the municipality bears only that part of the cost of the fire service which is not covered by the cost for private hydrants, standpipes and sprinkler systems, and when the cost for the latter is borne by those who use them, the situation is more complicated. For in such cases, in addition to providing a rate for the municipality, it may be necessary to also provide detailed schedules for each of the private systems.

In the case of fire protection there is no very close relation between the cost and the number of hydrants on the system, providing of course, that the number of hydrants is sufficient to enable water to be provided as needed. Where it is the practice to place hydrants at stated intervals as extensions are made in the distribution system, there would be some slight relation between the number and the cost of fire protection, but the greater part of the cost is *not* due to the fact that the hydrants are installed. Should a municipality decide to place hydrants every 200 feet instead of every 400 feet, no more water would be needed for the protection, nor would the

demand upon the pumping station increase, and the only additional cost would be that represented in the amount of interest and depreciation upon the hydrants and the connections.

The demand upon the pumping station is determined by the fire risks in the district protected and may be expressed in terms of the number of fire streams of certain diameter and pressure necessary to make the protection adequate. Doubling the number of hydrants does not double the number of fire streams needed and the demand upon the station remains unchanged. Therefore there would be no necessity of additional investment in pumping station or distribution system, except the cost of the additional hydrants. The fire protection demand, which determines the investment required for protection purposes, is made by the district to be supplied, and consequently the interest, taxes and capacity expenses are dependent upon it and not upon the number of fixtures through which it must be exercised.

This does not mean that extensions of the fire protection system do not have an influence upon its cost. Should the distribution system be extended into a district not previously supplied with fire protection, the total fire demand of the whole community and the investment in the distribution system are increased. The fire risks of the enlarged area create the demand and the subsequent expenses, not the number of hydrants installed. When it is the practice to install hydrants at stated intervals, it is also possible to make a rate per hydrant. Fire protection is given to a certain area as a unit. For these and other reasons it has appeared to us that the best and most equitable method of providing for the cost of fire protection is to fix this charge at a lump sum based on existing conditions, and to provide for additional charges to cover interest and upkeep outlays on the cost of new extensions of mains, hydrants and other equipment, up to the point where the additions required affect the plant as a whole. When this point is reached an entire readjustment of all charges may become necessary.

It is obvious that there may be many disadvantages connected with charges based upon the extent of the distribution system or upon the number of hydrants. In order to furnish proper fire protection a plant should have a plentiful source of supply, adequate pumping facilities, mains that are large enough and so distributed that water may be delivered where there is a fire risk, and hydrants so placed as to serve to the best possible advantage. When charges are based on the number of hydrants it is inevitable that there

will be a tendency on the part of those paying the charges to limit the number of hydrants; or when a franchise requirement specifies a distance between hydrants on the distribution system the tendency may be to restrain the development of the distribution system itself. This latter tendency is also found in the case of plants using "per mile of main" as a charging basis, and in reality is the more pernicious as it not only tends to lower the fire-fighting efficiency of the system but affects adversely the general consumers in cases where both fire protection and general service are furnished. These and other facts inevitably lead to the conclusion that the cost of the fire service should be treated as a whole; that it should be charged to the municipality in a lump sum, and that the cost of new extensions to it should be covered by separate charges.

The question then arises, what effect does the existence of private fire protection systems have upon the plant? Are the total fire demand and the investment and operating expenses incident to this demand increased by these private systems? How should the rates for such service be made?

It is generally recognized that it is the duty of a city to furnish reasonably adequate fire protection. The utility must furnish enough water under sufficiently strong pressure to enable the city to supply adequate fire protection. Thus the fact that the city undertakes to furnish fire protection creates a demand which the utility must meet by incurring operating expenses and investment charges. It has been shown that the chief factor in determining the cost of a fire protection system is the demand which the utility must be in a position to meet. Does the installation of private sprinkler systems increase this cost? The city may be able to take from its hydrants sufficient water to meet the fire demand, but, because of the location of the hydrants and the character of the protection needed the water may not answer the purpose in all cases. In such instances the sprinkler system or private hydrants supply a means by which the water can more effectively be directed upon the fire at some given point. The total fire risk of the city would not seem to be increased by these systems any more than it would be by the placing of additional hydrants upon the existing mains in the streets. It is even conceivable rather that the effect of private systems of this kind is to check fires and to decrease the probability that the maximum fire demand will be exacted.

On the other hand there may be places where conditions are such that the private fire service tends to increase the investment or in-

vestment charges and possibly also certain items in the operating expenses. While the logic of the situation seems to be that the city, or the municipality, should bear the entire cost of the fire service, both public and private, there are many places where the municipalities have refused to assume this burden. There are in fact many places where the amount contributed by the muncipality for fire service falls far short of covering the cost of the same. In such cases the utility has little or no other choice than to make up the balance by correspondingly higher charges for private fire protection as well as for its domestic and commercial service. When it is necessary to fix rates for private fire protection of this kind the work involved in doing so should be guided by the same principles and proceed under such methods as those which govern the making of other rates.

One of the serious objections to sprinkler systems is that in the case of large fires the breaking of the sprinkler connections may cripple the fire-fighting forces by reducing the pressure. To eliminate this trouble, shut-off valves should be so placed as to be accessible in time of fire, as by the time the fire has become so serious as to need a large amount of water the sprinkler system has done its part. Improperly installed sprinkler systems which cannot be shut off in case of broken connections may be a menace to any water system, as is the use of water by secret connections. It is the right and duty of every utility to guard against this.

For the general service, or for domestic and commercial uses, the work of so distributing the demand plus the consumer cost on the one hand and the output cost on the other, that the unit costs obtained thereby may become fair bases for rates, is exceedingly complicated. It requires complete consumer and demand data. It further requires a correct distribution of the capacity and consumer costs upon this demand and a correct distribution of the output costs upon the water sold. While the unit costs which are thus obtained are of the greatest importance they may have to be considerably modified in the light of local conditions before they can be safely used as bases for rates.

The capacity cost should be borne by each customer in proportion to his demand upon the plant or the investment therein. This demand in turn is in a way measured by the size of the meter or service. A consumer having a 4-inch service pipe, even though he may use no more water than a consumer with a $\frac{3}{4}$-inch service, is in a position to demand and, normally, will demand more of the

capacity of the plant. This element is recognized in electric rates rather generally. There, however, it is practical to either measure the consumer's actual demand or calculate it according to his active load. The fact that this is impractical in the case of water consumers does not lessen the importance of the demand element. Inasmuch as the capacity and consumer expenses are in the nature of fixed charges which continue even if individual consumers use practically no water, the rate schedule should provide a fixed charge varying with the size of consumer's service or meter, and independent of the use of water. This is what is known as the service charge.

While it is difficult to determine the exact difference it is clear that many times as much water can pass through a 4-inch meter as through a $\frac{5}{8}$-inch meter. The ratio is dependent on the pressure, the character of the distribution system, and other elements, as well as upon the sizes of the meters. Meters of the same size will not be able to make an equivalent demand, unless conditions governing their use are identical. Because of these conditions, the apportionment of demand expenses among the various sizes of meters cannot be made with any such degree of mathematical accuracy as is practical in electric rate cases. The total capacity expenses must, however, be so apportioned that each consumer will bear them, to as great an extent as practicable, according to the demand of his service. The service charge for large meters must be large enough, in proportion to the corresponding charge for small meters, so that this purpose can be accomplished.

With the capacity and the consumer costs more or less fully provided for in a service charge, it remains to provide a charge that will cover the output cost. This can then be done by simply instituting a meter charge for a given quantity of water that is about equal to the average cost per unit obtained when the total output cost is distributed over the total amount of water sold. But conditions are not always normal. In some cases, owing to defective demand data, local conditions, and other causes, it is impracticable to cover the entire capacity and consumer costs in the service charge alone. When this is the case the costs which the service charge fails to cover must be added to the output or meter charges and will, to that extent, increase these charges. Such conditions, when met with, must, of course, be recognized in fixing the meter charges. They often make it necessary to institute meter charges that are gradually growing lower as the consumption or use of water increases.

The facts thus presented suggest a rate schedule for the general

service which is made up of a service charge covering the capacity and the consumer expenses, or as much of these items as is practicable, and of a meter charge of so much per 1000 gallons of water used. Owing to local and other conditions, there are instances when it is both advisable and necessary to keep the demand or service charge down to a comparatively low level. For similar reasons it may also be advisable to adopt meter charges which decrease in amount with each successive step of increases in the quantity of water used.

There is also another kind of rate schedules in use in which the principles of the service or demand charge are to some extent, at least, provided for. These schedules are made up of a minimum charge, graded according to the size of the meters or services, and which allow a certain quantity of water to be used under these minimums, which quantity is the same for all sizes of meters. In addition to this, these schedules also contain meter charges for all water used in excess of the minimum, which meter charges are the same for large as for small meters, and often so adjusted as to decrease with each successive increase in the amount of water used. Such schedules, when carefully developed, are often fair to all concerned.

When the larger users, such as a railroad company, will not avail themselves of the water of a utility at the regular rates or at rates which are materially higher than those at which they could provide their own supply it may be good policy to offer some reduction in the rates in order to secure their business. With reference to large users of this class, the water works is then placed upon the competitive basis. Whether such customers are desirable to the plant depends upon whether the rates at which they can be had are high enough to cover the additional cost of the service involved with something above this cost for fixed charges. If the rates they are willing to pay thus yield something for the fixed charges above the additional direct cost, then it is to the best interest of both the utility and its other customers that this service should be furnished, provided this can be done without unjust discrimination. For this additional service not only tends to reduce the cost per unit but to lower the fixed charges the consumers have to bear. The lower limit of such additional business rates is the point where they become either unjustly discriminatory or burdensome to the plant or the rest of the consumers. Competitive rates of this character are as a

rule best provided for either by the necessary adjustments in the meter charges or by separate schedules.

Rate schedules developed under the methods described seem to meet the requirements more fully than any other kind of schedules we have met with. It is true that these methods are laborious and that the distribution of the expenses under them must be made with the greatest of care. These facts, however, do not constitute vital objections to them. For the work involved is no greater than can be easily coped with. Close analyses of the various expense items and of the operating statistics and other facts involved disclose quite fully that sound bases can be had for the proper distribution of practically all common costs. The important questions in all work of this kind are for the most part concerned with the results obtained. On this point it can be said the cost method of rate making as herein outlined usually leads to rates that will not only yield the requisite amount of revenues, but that require each branch of the service and each customer therein to contribute their just share of these revenues. They provide like rates for like services under like conditions without unjust discriminations. Methods of rate making and rate schedules of which this can be said deserve more than passing notice.

In order to further illustrate the methods of rate making which have thus been described, they have been applied to the figures and facts for a typical water works plant owned and operated by the municipality. The cost of this plant and its business was about $150,000. On this amount the taxes, depreciation and interest charges at 6 per cent amounted to $9000 annually. The operating expenses proper footed up to about $11,586.60 for the year.

Of the fixed charges of $9000 the fire service was allotted $4800 or 60 per cent and the general service $4200 or 40 per cent.

Of the operating expenses of $11,586.60, the capacity cost amounted to $4374.13 or 37.75 per cent; the output cost to $5153.35 or 44.48 per cent, and the consumer cost to $2059.12 or 17.77 per cent.

When of this demand cost in the operating expenses 54.5 per cent is allotted to the fire service and 45.5 per cent to the general service; when the output cost is divided on the basis of 2 per cent for the fire and 98 per cent for the general service; and when the fire service is made to bear about .5 per cent of the consumer cost and the balance thereof goes to the general service the results are about as follows:

	FIRE	GENERAL
Capacity	$2,383.90	$1,990.23
Output	103.07	5,050.28
Consumer	9.77	2,049.35
Totals	$2,496.74	$9,089.86

When the $2496.74 for operating expenses of the fire service are increased by the $4800 which this service is made to bear for the fixed charges the total annual cost of the fire service is $7296.74.

When the operating expenses of $9089.86, as above apportioned, are increased by $4200 for fixed charges or for taxes, depreciation and interest, and when these fixed charges are allotted to the capacity output and consumer cost on the same basis as the operating expenses the total cost for each of these classes and for the general service as a whole is as follows:

For General Service Only

Capacity	$3,576.99
Output	6,919.70
Consumer	2,793.17
Total	$13,289.86

When for the general service the consumer cost of $2793.17 is distributed among the 1200 consumers of the plant the average for each is $2.33. When the output cost of $6919.70 is distributed on the 150,000,000 gallons of water sold, the average cost per 1000 gallons is about 4.61 cents. The number of meters and services used and their sizes were about as follows:

SIZE IN INCHES	METERS
⅝	1,100
¾	50
1	20
2	15
3	10
4	5
Total	1,200

The following table shows the consumer charge per consumer, the capacity charge for each of various sizes of meters and services

and the total for both. This total in rate making is often included in one charge which is named "service charge." The table also shows the total revenue for the year that would be derived from such "service charges." It will be noted that the total amounts to $5900 or to $470.16 less than the sum of the capacity and the consumer costs given above which amount to $6369.16, or to $3576.99 for the former and to $2993.17 for the latter. This difference arose mostly from the fact that round figures were used in computing the capacity charges per each class of meters. This balance of $470.16 can easily be cared for by a readjustment of the figures or by including it in the output cost which is the basis for the meter charge.

Total Service Charges per Year

SIZE OF METER	TOTAL SERVICE CHARGE	CONSUMER CHARGE	CAPACITY CHARGE	NUMBER OF METERS	TOTAL REVENUE FROM SERVICE CHARGE
⅝ inch	$4.00	$2.32	$1.69	1,100	$4,400
¾ "	6.00	2.33	3.69	50	300
1 "	10.00	2.33	7.67	20	200
2 "	20.00	2.33	17.67	15	300
3 "	40.00	2.33	37.67	10	400
4 "	60.00	2.33	57.67	5	300
Total					$5,900

When the demand costs are assigned to the meters and services somewhat in proportion to their size it is thus found that the cost per meter or service will also vary with the size of the same.

These figures suggest a rate schedule for the general service in which the service charge per quarter ranges from $1 for the ⅝-inch meters to $15 for the 4-inch meter plus a meter charge of 6 cents per 1000 gallons of water for the first 40,000 gallons and about 4.5 cents per 1000 gallons for all consumption in excess of this. This schedule on the basis of the conditions given would yield a trifle more revenues than the cost for the general service as given above, which was about $13,289.86.

These figures and facts suggest further that the cost of the fire protection service as represented by $2496.74 for operating expenses and by $4800 for taxes, depreciation and interest and that the sum of these items which is $7296.74 should be to the city as the annual charge for such protection.

DISCUSSION

Mr. John W. Alvord: We are very fortunate, indeed, to have had this paper by Mr. Erickson on this subject at this time. Such papers, as you will readily perceive, require careful rereading; and on a careful rereading you will find that Mr. Erickson has stated the fundamental principles of rate making very clearly and very concisely.

The fundamental principles of valuation are not formulae which the conviction of one man, or one set of men, or one interest, or one set of interests, arbitrarily set up; they are fundamental truths discovered by sound, logical reasoning, after having developed all of the viewpoints and all of the data which go to form the basis of such reasoning.

If in these fields of enquiry a solution is announced which is not based on sound reasoning it falls of its own weight; nobody has to dispute it, nobody has to undermine it, nobody has to controvert it; it simply falls of itself. But if it is based on sound reasoning it remains, no matter who denies it or who is disconcerted by it, and this whole question of rate making and valuations has thus come to be the result of a great many minds working along the same general direction, each seeking to find that sure basis, that elementary foundation of sound reasoning and justice which is fundamental.

On a careful study of Mr. Erickson's paper you will find that his conclusions are thoroughly sound, thoroughly well taken, and only arrived at after careful study and years of experience with his commission work in all phases of this difficult subject.

Mr. Daniel W. Mead: The speaker has not a great deal to say on the subject of rate making except to express his appreciation of Mr. Erickson's valuable paper. The last few years have witnessed a very decided change in the basis on which rates are made. Formerly, the question of what our neighbors were doing, the rates which were made in other communities, was very largely the basis that governed the making of rates, regardless of the expense of construction and regardless of conditions under which a plant was to operate. The consideration of such conditions is largely past. It is clearly a matter of equity that all the conditions that surround a water works plant must be taken as a basis on which charges are to be made, if such charges are to be just to the community and to the investor in water works securities. The pressure at which

water is delivered, the expense of securing good water, and of the purification and clarification of a water, must all be considered in determining the just and equitable rates which should be established. These matters were for years ignored or very largely lost sight of, but latterly we have witnessed a very decided change since these matters have been taken up and studied from a scientific standpoint.

As Mr. Alvord has said, just principles of rate making are coming to be recognized, and are so very clear that they are no longer matter of opinion but matter of fact, being founded on logic, justice and equity.

Mr. J. N. Chester: Having in view the difficulties which we have met that have arisen where cities were largely supplied on flat rates, and in the rate making process, it was determined to adopt the meter system wholly. Of course the charge for fire protection could be figured out with less difficulty than we could prepare an entirely new meter schedule that would produce an equitable return or fair return such as was expected from that character of revenue; has the Wisconsin Commission met with such propositions, and have they not found it necessary to put into effect and try out a schedule possibly for a year, then modifying that schedule to create more or less revenue in accordance with the original desire; not that we cannot tell what we want as a whole, but how we can distribute it in a sliding meter schedule that will hold railroads and commercial consumers that may be located along a stream and could pump their own water, and also be fair again to the small consumer and yet produce that portion of the revenue allotted to this service?

Mr. Halford Erickson: The Wisconsin Commission has only too often met with the very condition you have in mind; and we are trying to meet it the best we know how. In order to be able to meet it as well as possible we have gathered together all the possible data we could find or discover bearing upon the probable use of water under various conditions; and then with those data before us we have endeavored to assume what the probable consumption will be for the various branches of the service under those conditions, or under any given conditions.

We then make a service charge as a rule based upon data which nearly always can be determined, and you can also determine interest charges, depreciation, taxes, etc. But when you come to make the meter charge there is where you meet with trouble. In

that case we have to depend upon assumptions based upon the best available data. We have to put in effect rates made upon this assumption, for a year or so, or until they have been tried out long enough to show whether they actually give the requisite amount of revenue, or not. If they are found not to yield revenue enough, they will have to be increased. We have very often had to change them after a year or so of trial; but that is about the best that can be done in cases of that kind.

Mr. Leonard Metcalf: Mr. Erickson has presented the subject to you admirably, and absolutely fairly.

It is generally conceded today that rates must be predicated upon cost essentially in the final analysis. In the making of rate schedule, of course two general factors are involved; the first involving the question as to what shall be the entire return on the property; the second, what shall be the method of distributing the charges. Just at the present time one of the things which the speaker thinks is of the greatest importance to us in this country, at least in certain sections, is the question as to what shall be the total return upon the property in question. That today seems rather the more important question, rather more important than the question as to the distribution of the charges. It is the outgrowth, of course, of the experience through which we have been passing in the last few years, the attitude of the public toward public service corporations, whatever the causes of that attitude may be.

That we are coming to a general supervision of our public utilities, the speaker does not question. Personally he thinks we have little to fear from that supervision. We, of course, have watched the work of this particular Commission, the Wisconsin Commission, with the greatest interest and greatest admiration, for they have done splendid work. Some of us, we in the east at least, feel in certain of our states that the pendulum is swinging a little too far the other way in the matter of limiting the return upon property of this sort; and the anxiety we feel is lest the reduction shall be so great as actually to impair the character of the service which we shall get from our public service corporations, and lest we shall make conditions of service so drastic as not to attract capital to works of this sort.

Any public service commission is in an exceedingly difficult position. Any body of men placed in such a position must desire to be

absolutely fair in their relations and in their dealings both with the public service corporations and with the public; and as the result of the pressure which has been placed upon them, the margin allowed them for decision is growing smaller and smaller.

The basis of determination of the return upon capital invested in ventures of this sort is becoming more and more clearly defined; and in that work the Wisconsin Commission has been of the greatest service to us.

In the matter of distribution of rates also a great deal of progress has been made. Mr. Erickson has outlined the two general methods which have been used and which are not very different in their final results although the steps of arriving at such final result may be quite different. Each method results in a sliding scale under which the user of a small quantity of water pays more for that quantity of water, for the water which he uses, than does the larger user, although the scale may be built up upon the theory that all users pay the same amount for the first increment of water. When dealing with the making of a schedule of this sort, one of the difficulties, which have already been referred to by Mr. Chester, is that of making the transition from the flat rate basis to the meter schedule; and in this work the commission, of course, has a tremendous advantage over the individual or the commission to whom may be entrusted the revision of the rates, because it does not often happen that a commission of that sort has the opportunity of revising its opinion or recasting its work after having put into effect the schedule; and under these circumstances supposedly justice is much more likely to be done by a commission which can follow up its work than by a board sitting upon such questions, rendering its decision, and then going out of office. In such cases it is, of course, very desirable that there should be an opportunity for revision of the work of such a board, it seems to the speaker, after the establishment of the rates.

In this connection it is also perhaps of interest to mention the fact that the existing conditions in any community are likely to have more or less effect in the establishment of a rate schedule. For even when a study has been made in such a detailed manner as indicated by Mr. Erickson, there are after all certain factors, elements of judgment, which may vary the schedule to a considerable extent; and under those circumstances it is obviously more desirable from the community's point of view that the existing order of things should not be disturbed any more than necessary; because

many contracts have been made and other contracts are dependent upon the expense of the water, as, for instance, the cost of the railroad service, or freight rates, or whatever the service may be which would be seriously affected by any substantial change in the distribution of the charge.

There is one matter referred to in Mr. Erickson's paper to which the speaker would like to allude, and that is the matter of distribution of the hydrant fire service charge, as to which Mr. Erickson stated that according to their practice they based the charge upon the relative cost of furnishing an independent service.

It is perhaps interesting to note that another method which has been used is based upon the assumed relative cost of a single pipe furnishing a double service, rating the charges for the two services on the relative capacity and demand of the two services upon that pipe system.

The speaker is exceedingly glad that Mr.Erickson has referred so pointedly to the commercial considerations which are often involved, such as the railway consumer. That is a very real situation, and it is one which is exceedingly difficult to anticipate in making new schedules when passing from a flat rate to a meter basis of rating; and it is one which the speaker believes has perplexed the courts very much; so that an authoritative statement coming from such a source will be of a great deal of assistance.

Mr. Allen Hazen: The speaker has followed with a great deal of interest the development of the basis of rates that have been worked out in Wisconsin, and he has been very much pleased to see the logical way in which the subject has been developed by the Commission. To prove to you that he regards the basis that has been reached as a logical one, he can refer you to a little volume called "Clean Water" which he wrote six or seven years ago, in which a system of water rates was outlined very similar to the one that has been adopted. He feels very much flattered to think that he was able to anticipate at that time so much that the Wisconsin Commission has subsequently found to be best.

The speaker was very glad to hear from Mr. Erickson that there is more danger to consumers in low water rates than in high rates. This confirms the belief that he has held for years. Very few people believe this but it is absolutely true. Water service is enormously valuable to the takers. So much so that if it could not be otherwise furnished, they could afford to pay ten times what

they now pay for it. Improvements of the service, such as improvements in the quality of the water and in the pressure are almost always worth many times more to the consumers than the actual cost of providing them. A water works plant that has good rates is generally up to date, it generally is under good management and is a good plant, but when a plant has too low water rates, there is not very much that can be done for it with a deficient revenue. It does not make much difference whether it is owned by a city or a company, the service is sure to be poor.

Mr. F. C. Jordan: In the city of Indianapolis the Chamber of Commerce, composed of some of the best citizens, carried on a campaign of education relative to matters of importance to our city, and among the gentlemen who presented interesting papers in connection with this campaign of education was Professor Pence of the Engineering Staff of the Wisconsin Public Utilities Commission, who presented a paper on the value of the Engineering Staff in Public Utility Regulation. Professor Pence handled the subject exceptionally well and gave in some detail the various lines of work carried on by his department. The paper made a very good impression in our city, and one of our ablest men made the remark afterwards that if it took forty pages to chronicle the work of one department of the Utility Commission, he felt that it would be desirable to leave the matter of Utility Regulation in the hands of experienced men who had given the matter most careful consideration.

The speaker firmly believes that, with a commission as fair as the Wisconsin Commission, and a commission of the caliber of our present Indiana Commission, many of the points which we must consider at these meetings will be taken care of in a satisfactory manner by these commissions, and that our water companies will be free from many of the annoying features which not only perplex the present day superintendent, but at the same time absorb time which should be given to the betterment of his plant.

Mr. H. A. Dill: This paper has been of very great interest to the speaker particularly because, as Mr. Jordan says, Indiana has recently enacted a new Utility Commission law which went into effect on May 1st. The company that the speaker represents has taken advantage of that law, and taken an indeterminate permit as provided by this law. The company has been negotiating

about four years with the city trying to solve these different problems. In view of the precedents that have been established by the Wisconsin and other commissions, we are in a very good position to obtain fair treatment not only for the company but for the consumer.

Mr. Erickson's statement in regard to sliding scale rates was very gratifying, and every water works man sees the advantage and the absolute necessity of such a scale; yet there is a class of newspapers, of which we have one representative in our community, that make a practice of assailing sliding scale rates on the ground that there should be uniformity all the way through, and that the small consumer should not pay more than the larger consumers, such as railroads. What sound basis can be found to support such an argument is something that is beyond comprehension.

Mr. Frank L. Anders: We have recently made a complete change in our method of water supply in Fargo, and the problem of rates has been forcibly brought to our attention. Formerly it was necessary to use water from four different sources. The water from the river which was pumped through the mains was so turbid and so badly polluted it could only be used for flushing, sprinkling and fire protection. Rain water, caught in cisterns, was used for washing and bathing; artesian water obtained from wells and transported in wheeled vehicles, was used for cooking, and a bottled water was used for drinking and table water. Thus it is seen that the cost of water in this city was a large item to the resident. In 1912 a water purification plant was installed which made it possible to use the water from the mains for all purposes. We have no meters and the consumption is over two hundred gallons per capita per day, and as our manufacturing consumption is small, the waste is very great. In order to get to a proper financial basis we have had to adopt the meter system and the meter rate. This has not been accomplished easily.

Due to improper accounting it appeared that the old plant was making a profit, for bonds, interest, renewals and new construction were paid by taxation, and all revenue from rates, above that used for labor and coal, was declared a profit. The present policy is that the plant shall be self-sustaining, and we have found that the old flat rates would not accomplish that. Naturally the people feel aggrieved that a system which formerly made a profit of $20,000 to $40,000 is now suffering from a deficit of $25,000, and the

flat rates must be raised, consumption curtailed, meters put in and general economy practiced. But taking all these things into consideration, the total cost of water is much less than formerly. If we could have had a number of our citizens here to listen to this valuable paper and the discussion this afternoon it would certainly have enlightened them as to difficulties the water department has to contend with and no doubt would, as a result, uphold our endeavor to supply them with pure water at reasonable rates.

Mr. Henry B. Morgan: You have heard from Ohio, Indiana and North Dakota. Now the speaker wants you to hear from a neighbor of Wisconsin, Illinois. The gentleman from North Dakota said that they get their water from the Red River of the North. The speaker attended a convention several years ago of the Lakes to the Gulf Deep Waterways Association; the governor of North Dakota spoke in that convention and referred to the way that we treat our waterways. He said, "We have a river in North Dakota that comes down from Canada, and gets so disgusted with the way we treat our rivers that it turns around and goes right back again."

The Wisconsin Utility Commission is doing a great work. Its two main objects are: First, to see that the people get good service at reasonable rates; Second, to see that the people who invest their money in public utilities get a fair return on their investment. Fair treatment and fair return on the investment is all that any of those who represent utilities want. It is well known that municipal plants are often managed so as not to secure the necessary financial return to meet the cost of operation, and at rates correspondingly low. They sometimes are totally indifferent as to whether the plants are on a paying basis, provided some political end is achieved and they can boast of supplying cheap water. To compare such rates with those charged by a privately owned plant is manifestly unfair. In many cases a water works plant is no sooner constructed and in operation under private ownership than a howl is raised about the rates being too high. That sort of a complaint has been made in our locality for twenty-two years and it is still going on. There has been no change in the rates during that time, but there has been continued agitation although we are being treated much better than we were five years ago, due in large part to the work of the Wisconsin Commission.

Mr. Dow R. Gwinn: Before the discussion on this paper is closed, the chairman believes that some formal expression of our appreciation should be tendered Mr. Erickson for taking the trouble to come to Minneapolis and present to us such a valuable paper, which no doubt will be quoted many, many times throughout the United States. Our members will have occasion to refer to this paper a great many times in discussing rate problems, such as are constantly coming up in the various cities.

The speaker was particularly pleased to have Mr. Erickson refer to *unjust* discrimination. His use of the term "unjust" discrimination indicated that in Mr. Erickson's opinion there would at times exist a discrimination which was necessary. Certainly in the water works business while there may at times be discrimination, it does not always follow that this is unjust discrimination.

The speaker was also interested especially in the statement of Mr. Erickson with regard to the fact that proper safe-guarding of the public's interest as affected by water supplies demands reasonable rates, reasonably high rates, if you please. The interest of the public makes it imperative that the rates shall be high enough to insure adequate service. As was well said by Mr. Erickson, and by Mr. Hazen and others who took part in the discussion, it is not within the bounds of possibility to furnish good service except at adequate rates. This applies to municipalities as well as private companies.

Mr. Erickson also spoke of the determination of rates being largely dependent upon local conditions. Of course we all agree with what Professor Mead so well said, that the fact that some other city charges a certain rate does not necessarily render it possible for the same rate to be maintained elsewhere and insure proper service.

The speaker was also especially pleased to hear Mr. Erickson refer to the fact that when a water company furnishes water to a railroad at low rates this really means that some of the other consumers will receive their supply at a lower cost than they would if it were not for the railroad being supplied. It is very difficult to make the average city politician believe that; in fact, he refuses to give it any consideration at all, and declares that the smaller consumers should have the same rate as the large consumer; whereas on the contrary it is manifest that the water company or water department, because of furnishing a large amount of water to a railroad, for instance, at a much lower rate than to the smaller

consumer, is enabled to pay the fixed charges on the investment and thereby furnish water to the smaller consumer at a less rate than would be possible if it were not for the railroads or other large consumers. Again, if large consumers, like railroads, are charged too high a rate they will pump their water supply themselves, if it is possible to do it, and thereby the water department or water company will lose.

PROF. R. L. SACKETT: One of the great values of a commission of this kind, judicious and careful as it is, is that it creates in the people a certain confidence which they otherwise would not have, and removes these questions from the arena of political controversies and intrigues which often complicate the situation and tend to depreciate investments in water works corporations. While the interest rate itself may go down slowly as time goes on, as is the case in other investments, the confidence of the public in such investments through the intervention of public utilities commissions at this time will be correspondingly greater and will perhaps help a little to improve conditions in the water works business, where otherwise the decrease in the interest might prove a serious detriment, as was mentioned by Mr. Metcalf. It may assist somewhat in placing the business on a more substantial footing, securing proper income and at the same time distributing the rates among consumers more fairly than has been the case in the past.

HYDRAULIC ENGINEERING EDUCATION

By Daniel W. Mead

All who have given much thought to the subject of education will agree with the writer that the purpose of education is not so much to impart knowledge as to train the student to acquire knowledge. The purpose of technical education, therefore, is not so much to impart technical knowledge to the student as to furnish the training which will enable him to understand and investigate the conditions which surround a problem, to determine the fundamental principles on which its successful solution depends, to ascertain and analyze the elements which influence or modify it, to design the structures and works needed for its successful development and to supervise the proper construction of such structures or works and carry them to a consummation of successful and economical completion. This, in the writer's judgment, is the essential aim of engineering education.

The engineer must have a comprehensive understanding of the elements that underlie his problem and on which its proper solution depends. He must know what and how to investigate, and how to analyze and weigh the influence of every factor involved. He must be able to see or determine the value and effect of each element in the problem, and he must know where the knowledge needed for these ends is available, and how to acquire it. He must understand ways and means as affecting both construction and operation, and, so far as possible, he must have developed his judgment, sense of justice and equity, and common sense.

The amount of knowledge that can be retained in the mind at any one time is exceedingly limited, and in discussing education it must be understood that the time spent in the university course as well as the mental capacity of the student are both too limited for the acquisition of anything more than the elements of knowledge needed by the practicing engineer.

For the purpose of technical education, instruction is required:

1. In the fundamental principles of those sciences on which the practice of the engineer necessarily depends.

2. In those methods and calculations which must be applied in such practice.

3. There should be included to as great a degree as possible instruction in those human elements that concern the personal relationship of the engineer with his fellows, with his clients, with contractors, and with the public, and also those matters of judgment, equity and ethics on which the highest success of the engineer depends no less than on technical knowledge.

JUDGMENT

Judgment can be developed by experience only, but the tendency of technical education is rather to the detriment of judgment. If text-books and instructors are considered infallible, if their lectures and dicta are to be taken without question, the development of judgment is certainly not stimulated.

An earnest effort should be made to point out the limits of theory and the point where judgment and speculation begin. The use and abuse of formulas should be noted, and their limitations pointed out and emphasized. Every experienced engineer recognizes the convenience of formulas but also understands the danger of their careless application. The writer knows no better way to encourage judgment or emphasize the limitations of formulas than by a careful and detailed study of actual professional problems where the uncertainties are clearly pointed out.

The writer has had a great many young men in his employ in his private practice, and has found that in a great many cases they were largely dependent upon formulas with which they had become familiar in their college course, taking them often as absolutely dependable when frequently they were not applicable to the particular case at hand. Often, if their formulas were mislaid, the work that they undertook was essayed with great difficulty.

ETHICAL PRINCIPLES

One of the most important factors of technical education in every line is the ethical attitude which is necessary for engineering success. This cannot well be taken up as a special study, but should be introduced by instructors whenever the time seems appropriate.

Most practicing engineers recognize the fact that a true view of ethical relations is fully as important as technical knowledge, and no student should leave his university without being impressed

with the more important ethical principles. One of the most important of these is a knowledge of selflimitation, and an appreciation of the fact that success is mainly due to hard work and not to great brilliancy. The student must be brought to appreciate his own limitations and the meagreness of his knowledge, and must learn that success in any line is dependent on thorough, hard, conscientious and intelligent work. Most socalled men of genius have accomplished results by constant and unremitting application, by untiring drudgery, rather than by great brilliancy; and all that is most worth while in life is accomplished or secured in the same manner. Opportunity is undoubtedly important, but hard work usually creates opportunity, and no man accomplishes true success without these elements ingrained in his character.

Another characteristic of success is dependability. No amount of knowledge and no amount of work can take the place of this attribute. The man who can be depended upon is ever in demand and if he has also acquired a high degree of technical training and an appetite for hard work, his success, barring accidents, is undoubtedly assured.

The teaching of such principles is difficult but essential, and should be introduced in the technical course with professional subjects, and can, the writer believes, come best from those instructors of more mature years who are most closely in touch with practice.

While the average student objects to "preaching," the writer finds that no other subject so intensely interests a class of advanced students as those subjects which have to do with the relationship of the engineer to life and to the ethics of professional practice.

BREADTH OF EDUCATION DESIRABLE

All knowledge is more or less related, and every subject bears more or less directly on every other subject. It has been said that if any man knows all that can be known of any one subject he will know all that there is to be known of every other subject. Such a comprehensive knowledge is of course ideal and impossible of realization, but a broad foundation of many subjects is necessary to a true appreciation of any one subject. This is especially true of technical knowledge; and for a broad knowledge of any specialty it is both desirable and necessary that the student have a general knowledge at least of other specialties.

DANGER OF EXTREME SPECIALIZATION

There is, perhaps, no more narrow man than the specialist who knows nothing of aught but his specialty; he is an unsafe guide except along his own narrow lines, for when his lines cross or run parallel with other subjects, he has no true perspective of relative importance or of relative values.

It has been said that if you are sick and go to a tailor, his prescription will be a new suit of clothes. Every thoughtful engineer will realize that his personal experience and bias will influence his recommendation. Recently a proposition was under consideration that involved the installation of two pumping engines of six million gallons' capacity in a location where it was undesirable to construct a boiler plant and where in consequence power had to be transmitted in one form or another for about a quarter of a mile. Various electrical engineers who were brought into the discussion uniformly recommended the use of electrical generation and transmission. A large steamelectric installation was already available in the main plant, and the electrical engineers advised the use of that plant which, however, was about four times too large. When it was pointed out that the efficiency would be very low on account of the large size of the generating plant, the electrical engineers advised the installation of a steamelectric plant of proper size for the work to be done. After due consideration of the proposition, steam transmission, the steam pipes being carefully insulated, was installed. The steam consumption of the plant actually installed was about half of what it would have been with a special electrical plant designed for the service, and about one quarter of what it would have been with the large plant that was already installed; and at half, and quarter loads, at which points the plant operated a considerable portion of the time, the saving was very much greater. The error in the advice of the electrical engineers is, therefore, obvious. The tendency of the specialist is always to advise his specialty.

The writer believes that one of the most important elements in the instruction of the young engineer is to lead him to appreciate not only his own specialty but to give him a correct appreciation of the specialties of others. The engineer, who is educated in only one specialty and has not the knowledge necessary to compare it with others, is poorly prepared for professional life, and his training will not give the best results to either himself or his clients.

Specialization is, in the writer's opinion, a serious mistake if

carried far in a university course if the desire is to educate engineers instead of training skilled workmen.

The ideal university for the education of the engineer is not a trade school. The education should be largely general, and special branches should be handled so as to broaden and not to narrow the student; they should be considered with relation to other lines with which they may have to be compared.

ENGINEERING COURSES FAIRLY SATISFACTORY

In most branches of engineering, the courses of our engineering schools are fairly satisfactory. The principles and methods on which investigations and practice must rest are fairly well covered, and the young engineer when he leaves his technical school is fairly well prepared to undertake the minor calculations and designs in the practice of his profession but still needs experience, postgraduate study and investigation, which are necessary for more advanced work and can be obtained to the best advantage concomitant with the practice of his profession.

THE WEAKNESS IN HYDRAULIC ENGINEERING EDUCATION

In the teaching of hydraulic engineering there is a decided weakness in the professional courses pursued in most schools. The great loss of life and property in recent floods; the similar losses caused by the failures of dams and reservoirs within recent years, and the errors in estimating hydraulic resources, resulting in financial failure, partial or complete, of many hydraulic projects in irrigation, water power and water supply, point to the great need of fundamental education along hydrological lines both of the people as a whole and of engineers on whose shoulders more particularly rests the responsibility for the success of these various projects.

Since the recent disastrous floods, the lack of exact information has become especially apparent. A great deal of so-called knowledge concerning hydraulic and hydrological matters is simply speculation, or may even be classed as fable and superstition, which even a little investigation would show to be erroneous. As examples of these errors in which both business men and engineers are frequently involved, numerous instances might be cited. Mr. James J. Hill, in an article in one of the recent magazines, points out that the building of levees along the Mississippi River is a failure, because

the river is gradually building up its bed almost as fast as the levees are constructed. Now it is a fact which has been demonstrated by some 400,000 soundings by the Mississippi River Commission, that the Mississippi River is not building up its bed, and the proposition laid down as an axiom by Mr. Hill is entirely in error. Another popular fallacy is the universal adaptability of reservoirs to prevent floods, that reservoirs furnish the solution of flood prevention. In a recent paper by Colonel Townsend, President of the Mississippi River Commission, delivered at the Drainage Congress in St. Louis, he made the statement, which can be readily verified, that, taking into account the length of time in which the water would reach Cairo from Pittsburgh, St. Paul and St. Joseph, if at that time reservoirs had been constructed that would have cut off the flow of the Mississippi River above St. Paul, the flow of the Monongahela and the Allegheny above Pittsburgh and the flow of the Missouri River above St. Joseph, that, with all those great reservoirs in use nevertheless the height of the water at Cairo would have been reduced but six inches. The speaker knows of no better illustration of the limitations of reservoirs as a universal panacea for floods.

The writer received not long ago a letter from the editor of an engineering magazine calling attention to the control of the Chagres River by the Gatun Dam, saying he hoped that all engineers would unite in the recommendation to apply this same principle to the control of the Mississippi River. Could any proposition be more absurd? Even a layman should realize that physical conditions must control, and that no scheme of flood control is universally or even generally adaptable.

The popular clamor for waterways as a sure cure for commercial and transportation difficulties, regardless of detailed consideration and investigation, and the theory of the universal influence of forests in conserving, equalizing and improving the flow of streams, are examples of erroneous hydrological ideas that will not bear the test of careful and thoughtful investigation. These subjects should be so considered and discussed in a hydraulic engineering course that the future hydraulic engineer shall realize the necessity of careful investigation and the determination of the actual value and influence of a given structure or plan of development on the betterments desired, and not be misled by popular clamor and irrational assumptions.

NECESSITY FOR HYDROLOGICAL EDUCATION

Experience in the field has demonstrated the fact that more failures have resulted in various projects of hydraulic engineering from a lack of an adequate conception, on the part of the designing engineer, of the fundamental principles of hydrology and of the importance of hydrological factors, than from defects in the design or construction of the various structures involved. In many cases, the engineer has not possessed sufficient knowledge to appreciate the necessity for hydrological investigation and study, and very frequently has ignorantly made unwarranted assumptions and neglected any investigation whatsoever, because of the lack of such appreciation.

As a result of this lack of appreciation of the fundamental basis on which every sound hydraulic project must rest, we find numerous irrigation projects completed at large expense but without adequate water supply; water power plants constructed on streams not having sufficient available flow, or with such irregular flows as to make the projects entire or practical failures; spillways and gates in dams constructed with inadequate capacities for the passage of extreme floods; pumping stations constructed to utilize supplies of water which are too limited for the purpose for which they were intended, or with supplies polluted, or otherwise undesirable; communities and industries located in situations where they are subject to serious overflow and unnecessary flood damage; protecting works built with no adequate idea of the maximum necessities of the case, or their effect on flood heights; drainage enterprises undertaken with no adequate knowledge of the flood capacities which must necessarily be provided for extreme conditions. In many ways unnecessary losses are frequently entailed which have been due most largely to the fact that the attention of hydraulic engineers has not been called to the importance of hydrological information, the sources from which such information can be obtained, or the necessity and methods of undertaking hydrological investigation and study.

NECESSARY LIMITATIONS OF TECHNICAL INSTRUCTION

The subjects considered essential in technical education are so numerous that it is very evident that scarcely more than the barest outline of any technical subject can be acquired within the necessary limits of a university course; and it is of course manifest that in

the brief time available for professional studies in technical schools the lines of instruction must be more or less limited, and that a full consideration of any professional subject must be left for the investigation and study of the young engineer after he has begun actual practice of his profession. No professional study can be attempted except in a most elementary and incomplete manner; but in every case the student should receive instructions as to what to study, and how to investigate in his own special line of professional practice.

For example, the subject of water supply, which is treated in one semester in most universities, usually occupies the time of the student about one hundred and fifty hours, or the equivalent of fifteen or twenty days. During this limited time, instruction must be given in the entire subject of water supply, including the sources of supply, development of underground and surface waters, distribution systems, standpipes, reservoirs, pumping machinery and numerous other subjects. Any practicing engineer will spend usually more time than can be given to this entire subject on a single phase of a single proposition which may come before him. It is, therefore, obvious that such a course can cover only briefly the most important points, and that the student when he leaves his university knows nothing about the comprehensive subject of water supplies except how to investigate and study the subject. To instruct the student in methods of investigation and study is the only attempt that can reasonably be made in the teaching of any professional subject, such as water supply, water power, irrigation, drainage, etc. This in the writer's opinion is the object of such a university course.

THE CONFIRMATION OF TECHNICAL INSTRUCTION

Technical knowledge to be of the greatest value must be confirmed by practice. Even the fundamental principles acquired by the student become truly his only after they have been demonstrated under many conditions and in many places. When the statement of the teacher and of the text has been fully investigated and verified, then and only then is the knowledge truly acquired. It must, therefore, be understood that university work to be of real value must be supplemented by study, observation, practice and experience.

The deficiencies in hydrological training are well illustrated by

the following example: The writer had occasion only a few years ago to examine an irrigation project in the arid west that had been laid out by a graduate of one of our engineering institutions. The design so far as the structural features were concerned seemed to be excellent. When the question of water supply was discussed, the engineer in charge stated: "Oh, there is plenty of water, there is no question about that; I have been around that stream for several months, and I know there is always plenty of water." Later, when the matter was examined in detail, it was found that there was not over onethird to onefifth of the water that would be required, and the engineer finally remarked, "Well, to be honest, I did not know how to make an estimate of the water supply or how to investigate it."

On this same project an older and more experienced practicing engineer, who was in charge of a similar project costing over three million dollars, visited the same work, and a rain storm occurred so heavy that the gullies were running full, and he had to wait several hours before making some small creek crossings. From his chance experience, under most unusual conditions, he said: "Gentlemen, you have water enough to irrigate this whole valley." An investigation of the water supply showed so little water that the project was rejected as impracticable.

The writer has seen so many errors of this kind in his examination of various projects in the various lines of hydraulic engineering that he believes engineering schools should give some attention to this subject. He does not wish to imply that a great amount of time is necessary, but he believes that the attention of the student should be drawn to these important hydrological subjects and that some systematic course should be arranged, of limited extent, but which would point out the dangers in hydraulic projects of illadvised plans based on inadequate knowledge, and that the source and necessity of such knowledge should be made plain to the student, so that when the time comes he will know what his problem is and how to study it.

The teacher cannot expect to impart to the student the knowledge that can be assimilated only by long years of experience. Even the engineer in practice can keep in mind only those things with which he is in daily contact; he must look them up; he must study them; he must acquire and reacquire them as he needs them.

Educational ideals are by no means fixed; they must grow and develop; they must change with the times and the circumstances.

In the writer's judgment, most engineering courses can be greatly improved by a judicious introduction of the personal and ethical factors; and in hydraulic engineering courses much more attention should be given to fundamental principles which have in general been too long neglected.

The ordinary engineering course provides fairly complete instruction in mathematics, strength of materials, design of structures and in the calculation of those physical phenomena on which the practical success of engineering structures must depend. The whole training of the engineer emphasizes the necessity of a knowledge of the principle of design in order to give adequate strength and stability to the structures to be designed and installed; and, while errors in such designs are only too abundant, they are, in hydraulic engineering projects, much more limited than the more fundamental errors that are due purely to the lack of appreciation of the very element of the problem on which success most depends.

No engineer would attempt to design the physical structures of a water works system or water power plant without endeavoring to acquaint himself with the principles and practices on which the successful construction of such structures must depend; and yet, the water supplies on which the success of these projects is entirely dependent are frequently only superficially investigated, or the sufficiency of supply assumed. It would, therefore, seem illogical that our schools should provide instruction in these technical subjects which can readily be taken up by the engineer in postgraduate study, either in college or out, and fail to provide a thorough course in the fundamental underlying principles of hydrology on which the success of all such projects *must* largely depend.

A certain amount of professional study in a technical school is undoubtedly desirable inasmuch as such study permits instruction in the methods of investigation and design, and points out the application of the previous theoretical work of the student. It seems illogical, however, that such professional study should be pursued to an extent which will cause the neglect of a line of instruction so important to the ultimate success of the hydraulic engineer.

HYDROLOGY

Hydrology should treat of the laws of the existence and distribution of water over the earth's surface and within the geological strata, and of its sanitary, agricultural and commercial relations.

Hydrology should discuss hydrometeorology principally in relation to the occurrence, distribution, variation and disposal of rainfall and the runoff resulting therefrom, in drought and in flood. It should discuss the modifications of the runoff caused by evaporation, topography, geology, temperature, and various other factors, and the variation in runoff as the factors vary in importance. The great variations in the unit runoff under similar rainfall conditions but different physical conditions, and under similar physical conditions but different rainfall conditions, should be studied, and the marked differences which arise in different parts of the country depending on these differences in conditions should be discussed and appreciated. The effects of storage, of cultivation, of forestation, and of other artificial physical modifications of the drainage area on the flow of streams should also be discussed.

The study should include hydrogeology, or the occurrence of water in the strata, and the laws of its occurrence and flow. This must presuppose or include a sufficient study of general geology to give a comprehension of the geographical limitations which must be expected in hydrographic conditions, and the modifications due to geological changes. Water as a geological agent should be discussed, and through such discussion and study a comprehension of the birth, the growth and the development of drainage systems and of rivers attained. The apparent lawless and erratic action of streams will be thus found to follow laws more or less distinct and which must be studied and comprehended before intelligent river conservation becomes possible.

The rainfall and other accompanying phenomena are proverbially inconsistent; and yet the study of hydrology shows that there are limitations to such inconsistencies, which limitations are quite as narrow and exact as those that arise in other engineering fields which must be cared for by the "*factor of safety*," which is simply a "*factor of inconsistency*" in the qualities or occurrences of conditions with which the engineer always has to deal.

In the studies of water supply and sewerage which are offered in most engineering schools, various hydrological subjects are briefly discussed. In the study of geology and meteorology, which studies are sometimes included in the engineering courses, some of these subjects are also treated. Too often, however, mere facts and figures are presented concerning various phenomena, but such facts and figures are seldom correlated and the attempt is seldom made to establish relationship from which conclusions can be drawn and

on the intelligent use of which the success of hydraulic work must depend.

In no work on the subject of irrigation, with which the writer is familiar, is the relation of rainfall to runoff, or the value and limitations of comparative hydrography, discussed even in a limited way, nor is any method of investigation pointed out.

In very few instances is the subject of hydrology systematically taught in a manner sufficiently complete to afford a reasonable basis for the investigation and study necessary to the successful practice of the hydraulic engineer, or even to a sufficient extent to give the engineer a reasonable appreciation of the importance and necessity of such study and investigation. In many cases the student enters professional life with no appreciation of this subject, and with no knowledge of the availability of the great fund of hydrological information which has been accumulated at the expense of much time and labor, and through both the success and failure of many hydraulic projects. Surely our engineering schools should add this important subject of hydrology to their curriculum.

UNDERGRADUATE TRAINING FOR HYDRAULIC ENGINEERS

By Prof. O. L. Waller

It is the intention in this paper to discuss the advantages to be derived by means of or through a close coöperation in the engineering division with our irrigation companies, power and construction companies, municipalities, and similar organizations.

The writer desires to propose that educational institutions give academic credit for some of the field work done by undergraduates employed in engineering work during the summer vacations and at other times; and to suggest that it would be a good plan in many instances to advise the student at the close of his sophomore year to enter some engineering office at a moderate compensation for the purpose of studying its organization, getting acquainted with the way of doing things, and learning to associate with men and things. The writer readily sees that the granting of this academic credit could be carried to an extreme, but it has occurred to him that with proper handling the scheme could be worked out to the great benefit of the student and also the benefit of those employing his labor.

It is the writer's intention to discuss the question of the hydraulic engineer's education from the standpoint of what education he should have; and, how he should acquire it. In our early history of engineering, this training came almost entirely from practice; later, as a branch of physics, it became generally theoretical; then it vibrated to the laboratory, where we taught exact calibration, worked out some experiments and did some testing, but in so doing we almost entirely failed to cultivate the judgment of the student in dealing with the problems under field conditions.

The writer does not care to go very deeply into the subject of what should be taught the engineer, but wishes more particularly to discuss how he shall acquire his information, whether his knowledge shall be gained entirely from text-books, lectures and laboratories, or whether his judgment shall be trained in the field. If judgment in dealing with nature's problems is important, it is a

necessary part of his education, before he can become a useful member of society. The question then arises, should not the student be given some collegiate credit for the work done while he is acquiring this practical side of his education; or, in other words, while he acquires that side of his education which makes his theoretical training effective?

From first to last we have been asking those employing engineers what they would have us teach the boys in college. But after they have told us we find it impossible to turn out the product they most want. Much has been said and written of the failure of engineering graduates to measure up to the standard set by employers. It has been said that they are not careful and exact in figures; that their results cannot be relied upon; that they are not willing to begin at the bottom and work up, believing that they have passed the apprenticeship stage. The writer has not observed that the same criticisms are lodged against technical graduates in other fields of work than engineering. A good many reasons for these shortcomings have been advanced, some critics going so far as to brand the whole system of engineering training in colleges a failure. Some charge the trouble to the inexperience of the faculty, to a lack of knowledge on their part as to what employers and the general practice demand; to the fact that they do not keep in touch with the uptodate methods and practice current in the profession of engineering. Others find all the trouble in modern college life, too much athletics, too much society, too much fraternity, or too much club, too much time lost. They charge a wrong standard of habits, expensive habits, wines, tobacco, carousing, many things undertaken, few or none successfully completed.

They charge snobbery and men trained in snobbishness to such an extent that the engineering graduate cannot work on a level with the more humble laborers with whom he is thrown in contact, frequently as a directing head. In this connection it may be asked what effect did the removing the boy from home and restraints of good parents during a very formative period have on his habits? Has the college supplied the needed counsel, restraint and balance for his activities, or has it permitted him to behave like a motor without a balance wheel, or a load, and with the throttle wide open? While these points are vital the writer does not have the time to enter upon their discussion. They have been elaborated by other men and their observations are worthy of serious consideration. The writer wishes to confine the discussion entirely to the student's

usefulness to his employer. How shall he acquire engineering judgment and administrative ability? When and where is he to learn the method of attacking field problems, and of solving them?

Under the old apprenticeship method, the student's entire instruction came from practice. With the abolition of that system the major part of his information came from theory. The pendulum then swung to the laboratory which under ideal conditions supplies the necessary training in calibration and testing. But there is a demand for knowledge that cannot be gotten from any of these sources. It must come from actual contact with the business of engineering. Only in the field where nature's conditions are met and must be dealt with can the student acquire the judgment necessary to make his theoretical training effective, and this is better done after he has a foundation in theory. In college he learns to deal with men, and how to get on with those of his own rank, but he does not acquire skill as a directing, organizing head; nor does he learn how to meet and solve nature's problems with any large assurance of success.

In an irrigated country with its thousands of laterals, sublaterals, control gages, weirs and other measuring devices, when and where shall the student learn how to locate such laterals and headgates and to set such modules so as to secure satisfactory results? Only in the field, with overalls on, directing and actually doing the work for himself. He may have calibrated a weir in the laboratory, determined the efficiency of a pump, or measured the velocity of water in pipes, but when he goes out to run a test on a water system, he is required to adapt these laboratory methods to the conditions that obtain locally, and this power to apply is a large factor in his success. The writer could give very many concrete examples of the lack of judgment of young engineers in applying foundation theory to real construction. He once examined miles of flume designed and placed by a young graduate and found said flume was entirely incapable of carrying the quantity of water intended to be conveyed by its designer. The grade was right, the section was right, the construction was good, but the engineer had used theoretical values for (n) in Cutter's formula without considering the effect of alignment or the effect of earth, sand and other débris, on the bottom and sides of the flume. The water works and the sewer systems of many of our smaller towns are designed by young graduates shortly after leaving college. Not infrequently we find a 4-inch fire hydrant on the end of a $1\frac{1}{2}$-inch water pipe; drilled wells

high up on some hill, and sewer systems with no provision for flushing.

Contact with real engineering and with the broad gauged men executing such work would help the student to find himself professionally. Such an introduction to the real work of the profession would test his staying qualities and help him to find out whether he was suited to the profession or not. It would serve as a clearing house. Possibly a goodly number will find some other line of work more to their liking and would drop out of the profession; but this would be a gain, not only to the student but to the profession of engineering. At present the student graduates full of theory, some of it not well understood and much of it not assimilated by experience; and we send him out to gather engineering judgment, to revamp many of his habits, and in general to get acquainted with his profession as best he can. True, we have tutored him in the fundamentals of his profession but he has small experience in the application of these fundamentals. If some of that practice could be gotten before the senior year, so that his instructors might assist him in adapting and assimilating his experiences, thereby helping him to eliminate rubbish, and to organize and correlate the theory and practice, he would leave college very much better equipped to enter successfully upon his professional work.

The inefficiency of many college graduates is traceable to a want of judgment in dealing with conditions fixed by nature. A method of meeting and solving hydraulic problems cannot be successfully taught the student who has no field experience. It is not likely that the young hydraulic engineer will be able to control large heads of water under difficult conditions until he has had experience in harnessing smaller heads under less exacting conditions. He would not be expected to dam the great Columbia before he had acquired experience and judgment in controlling lesser streams.

Field experience in hydraulics makes a more efficient student. In the study of embankments, and earth fills, he at once recognizes the need of bond plowing and sees the necessity of exceeding the theoretical section for such embankments. Possibly he has been a ditch rider on a dry fill and knows the treachery of such embankments. He may have observed, measured and studied the seepage losses from canals constructed in the dust or through broken lava. He may have observed the excessive penetration, the waste of irrigation water near the head ditches. He may have been called into action to stop a break in the levee, to protect and save an endangered

structure from a rising flood, or to meet emergencies under other conditions, all of which experiences add to his useful knowledge, cultivate engineering judgment, sharpen the wits, and strengthen the initiative.

Particularly in the handling of water which is to be confined, or which has broken its bounds, prompt initiative and sound judgment, resting on a comprehensive knowledge of hydraulics, are at a high premium. These two qualities, theory, and engineering judgment based upon experience, seldom, if ever, are acquired together, and it may be discouraging to the young engineer to leave college with only the theory, particularly if more than that is expected of him by his employers.

A young engineer, a brainy fellow, a graduate from college with high honor, accepted employment with an irrigation company, and for his first job was sent out to run a line for a lateral which should carry water somewhere from a main canal to a group of small farms some two and a half miles away. A simple enough job, but where should the lateral be located, what kind of control works should be installed, how much water should the ditch carry, what would be the probable percolation losses, what grade could be secured, what section should it have, what velocity would the sandy loam through which it was to run stand, how were the two interposing ravines to be crossed and how were their flood waters to be taken care of, were some of the questions that confronted him. Part of them were easily answered from his school training, but the others presented difficulties that could be answered only from systematic observation, and experience in the field.

It is what the engineer knows that is useful to his employer. And he never knows a principle thoroughly until he has worked it out in practice. So far as it goes the laboratory does this, but it does not cover the great outside laboratory of construction and operation.

Can a college allow credit to apply on a Bachelor's Degree for work done by the student, in this greater laboratory during vacations or term time? And if so what credit should be allowed and what shall said credit stand for?

At the State College of Washington many of our engineers are self sustaining, have been employed on engineering work before entering college, and seek such employment during their vacations. This has given them a viewpoint that materially aids them in attacking problems in the classroom. They more readily grasp the

application of the theory to engineering practice and to field problems. We give credit on the college books for such work. Said credit is not a function of the time engaged in such employment, but of the net experience gained, and the grade awarded is not permitted to stand for the theory that goes with such practice. The theory may afterward be acquired from lectures or text-books, and is to be used as the digestive fluid by which experience is to be assimilated. There are some difficulties in the way of finding out how close an observer the student has been of the engineering work upon which he has been employed, how much he has assimilated, and of his adaptability to work with men and things. This information could probably be gotten at in two ways, partly by examination of the student and partly by a series of interrogatories addressed to his employers and to the engineer under whose direction he worked.

In discussing this subject of where or from what sources the engineer should acquire his working knowledge with some of the leading engineers, and city officials of the northwest, the writer finds that they all heartily commend the plan and have expressed a willingness to assist in carrying it out. If the student accepted employment for its educational value, the agreement with his employer should be conditioned on his being advanced or transferred through all stages of the work, even to the organization and administration end of it.

The field experience discussed in this paper will probably not result in developing the student into a fullfledged engineer. Experience, however, has shown that he is a better and more comprehensive student, that his conclusions are more rational and that he is the first man to find remunerative compensation upon leaving college.

DISCUSSION:

Mr. J. W. Ledoux (by letter): In the matter of education, if we look at the subject broadly, it is believed that all engineers will, upon reflection, agree that the ultimate purpose should be the intrinsic and material advancement of society; in other words, the education of the youth as well as the man in the practice of his profession should be such that when he finally finishes his work in this life, his influence will have been of permanent benefit to society, and that he has left it on a higher plane than when he entered. Therefore, in considering any particular phase of educa-

tion, the first question should be, does it fulfil these fundamental requirements? In most discussions on this subject other purposes are generally given. For instance, that education is considered best which enables the man to make a better living, to become a better mixer with his fellow man, to have more culture and refinement, to be more peaceable and to have at command the possession of more facts and information. None of these things fulfils the axiomatic object above given.

The inventor of a process for performing a given amount of useful work for less labor, even if he be unsophisticated, uncultivated and unrefined, has performed more real service than one who possesses a fund of popular information and is generally recognized as a good fellow in society. The knowledge of history and foreign languages and social usages is of absolutely no value unless it tends to the ultimate advancement of society.

The trouble with a good deal of education is that some of the most important matters are entirely neglected, and those which are not are taught with insufficient thoroughness to become of practical value. It seems too bad that our recognized public methods of education have not kept pace with the advance of science, and in the writer's opinion, there is no treatise on education and practice in this line that is equal to that recommended by Mr. Herbert Spencer as far back as 1860. The schools and colleges of today would make an immense advance if they followed out his scheme verbatim.

The education of the young man may be likened to the tools of a workman; there are very many poor workmen who have good sets of tools, and there are also many men of fine educational training who cannot apply it to any practical use—the two purposes should be combined in the schools and colleges, viz., the tools and their application. What is the use of giving a man three or four years training in a foreign language when this training is not sufficiently thorough to enable him to use it practically? How many men are there who have obtained mathematical diplomas in academies and colleges, who are not able to determine the fifth root of a decimal by logarithms, or work out the simplest practical problem in calculus? This kind of a training is worse than nothing, because, while spending the time over it, other things of value are being missed.

As to the curriculum, the essentials are, first, the English language, because its acquisition enables one to study other desirable things;

second, mathematics, without which we are not able to go very far in the sciences; third, natural laws, and one of the most important of these is the law of gravitation, which is the basis of all mechanics, but these laws, which are eternal and immutable, are so multitudinous that it is impossible for any individual to have expert knowledge in more than two or three, but their study constitutes the greatest education.

Our schools take up too much time with the study of phenomena instead of the laws or principles upon which these phenomena depend. As an instance, the study of history is of no value except in its bearing on sociology, or the law of society.

The laws of electricity, heat and light constitute in themselves a life study; the same may be said of biology or chemistry.

To go very far in his profession, it is necessary for an engineer to be thorough, and, therefore, specialize in some particular branch. On account of the present constitution of society, a young man is very seriously handicapped in his choice of an occupation in which he could be of the greatest benefit to society, the paramount practical consideration being to adopt that pursuit which will enable him most certainly to make a living for himself. Therefore, the world loses the benefit of the fine qualities that exist in many young men in lines in which they are better fitted to follow, but they are deterred on account of fierce competition in the commercial world. Frequently a man who should have been a miner or a farmer is a vender of groceries, and the man best adapted for hydraulic engineering is engaged in the baseball or advertising business, because it pays better.

Coming down to a concrete case, the writer is of the opinion that the best training for the hydraulic engineer consists in English, arithmetic, the elements of algebra including logarithms, plane geometry, plane trigonometry, a practical working knowledge of elementary general geometry and calculus, descriptive geometry, elementary physics, elementary mechanics and hydraulics, the use of the engineers' compass, transit, level and plane table, elements of lithology, mineralogy and geology, the elements of choice, chance and probabilities, physical geography and meteorology, mechanics of materials, resolution of forces, graphical statics, stresses in framed structures, free hand drawing, mechanical drawing, the properties of steam, the principles of prime movers, the use of the indicator, and the use of the slide rule throughout the course.

All these subjects should be taught with thoroughness, and the

only way to do this is to have abundant practical examples and problems for solution. The subjects of lithology, mineralogy, and geology, each constitute a life's work and, therefore, it is not expected that the student can do any more than be grounded in the fundamental principles. For instance, the expert specialist in geology is familiar with all the known signs of the rocks, such as lithological, mineralogical, chemical and paleontological, and even then, can necessarily be a specialist in only certain phases, such as iron ore or coal formations, but in the curriculum above given it is only intended to cover the general sequence of the formation of the earth's crust and the ability to recognize these formations from their general appearance. To do this it is necessary to have a good understanding of lithology, and to understand lithology well, it is necessary to know mineralogy.

In the writer's opinion, it is of great advantage for the student of hydraulic engineering to have actual practice either during or before the course, and for this purpose the correspondence school or the night school is believed to have, in some respects, an advantage over the strictly college course, because the former can be carried on simultaneously with practical work.

Nothing has been said concerning the training of moral character, the study of hygiene or sanitation, artistic development or culture, but all these matters are left to the individual.

The above is a formidable array of subjects in hydraulic engineering; nevertheless, they are mostly essential and there are many other subjects omitted which a great many engineers would include in the curriculum, such as, for instance, chemistry, metallurgy, thermo-dynamics, electricity, dynamos and motors, kinematics, machine design, foundry and machine shop practice, electro-chemistry, bacteriology, botany, scientific management, accounting, shorthand writing, French, German, Spanish, Latin and Greek, stereotomy, carpentry, building construction, foundations, masonry, roads, streets, and pavements, landscape gardening, roofs and bridges, reinforced concrete, jurisprudence, including the laws of business, contracts and specifications, political economy and literature.

But, even after a thorough preparation of the subjects above recommended, the education is only begun, and by the earnest engineer, is pursued in after years with practical experience in his own particular line of work.

WHAT THE YOUNG ENGINEER SHOULD KNOW ON ENTERING HYDRAULIC ENGINEERING PRACTICE

By John C. Trautwine, Jr.

To a young man, entering what is called "political" practice, a veteran "politician" gave this advice: "Find out which way the procession is going, and get in front;" and, whatever technical training and knowledge "the Young Hydraulic Engineer" may have "on Entering Hydraulic Engineering Practice," it will do him no harm to look about him, and (before getting in front) see which way the procession is going.

A paper, presented to the Western Society of Engineers by Dr. C. P. Steinmetz on October 25, 1912, and printed in that society's *Journal* for March, 1913, throws valuable light upon this subject.

Dr. Steinmetz's paper is entitled "Future Problems of Electrical Engineering;" but the problems suggested by him are present problems; and, although illustrated by electrical practice, they are industrial and social, rather than electrical.

Dr. Steinmetz might, therefore, have omitted from his title the words, "future" and "electrical," and might have called his paper simply "Problems of Engineering." His illustration, drawn from the field of electrical engineering, must appeal strongly to the "Young Hydraulic Engineer;" for, in these days of water-power development, whatever affects electrical engineering, must also affect hydraulic, though perhaps not water supply, engineering.

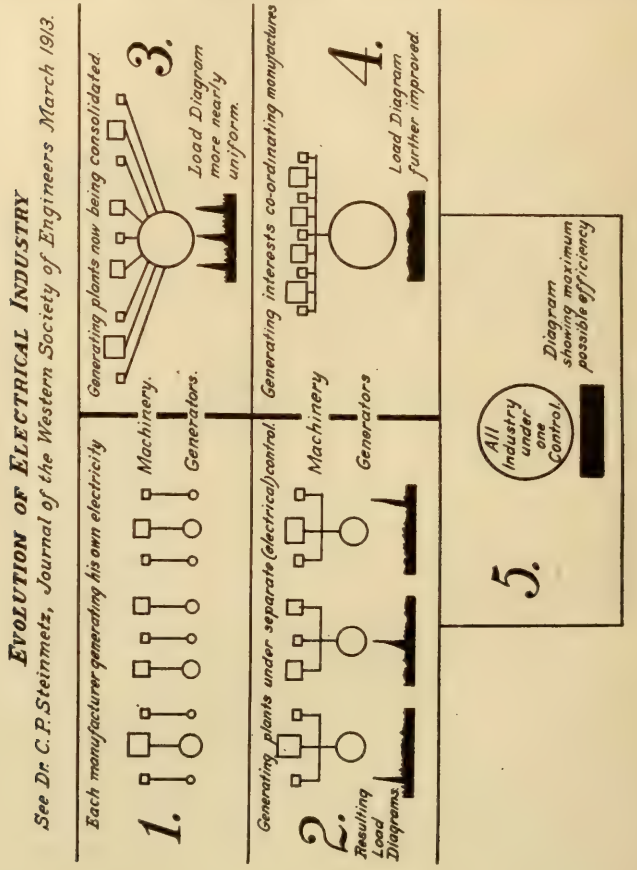
Dr. Steinmetz's paper points out the route of the procession, and brings his lesson more closely home by means of diagrams, intended to illustrate the several stages at which, according to his paper, electrical engineering has successively arrived, and that which it must next take.

These stages, four in number, arranged chronologically, and illustrated, respectively, by my figures 1 to 4, are briefly as follows:

1. In the beginning it was the fashion for manufacturers using electrical power to install each his own little electric generating

plant, producing, for himself, the current required for his own purposes.

2. But the generation of electricity soon gravitated away from the hands of the manufacturer of other utilities and into the hands of men who confined themselves to it; for it was found that, by thus specializing, they could employ and coördinate the services of



higher class engineering talent, and, by generating electricity upon a larger scale, could of course produce it more economically.

3. And separate plants, for the generation of electricity, are now gravitating from separate to combined control; bringing, of course, their clientages also under that one control, so far as their supply of electricity is concerned; for it is found that single generating

plants, of moderate size, and each serving only a few manufacturing plants, as in Figure 2, are at a disadvantage because of their low "load factors," each of the few manufacturing customers of one generating plant having his daily and seasonal peak loads, and thus requiring a large supply of current during a short time; while, during the rest of the time, he requires but little. With but few such customers, the generating plant, which must be of a capacity capable of meeting the *maximum* demand, must lie idle or only partly employed during much of the time. This is obviated, as in Figure 3, by combining a number of separate generating plants into a single large system, thereby combining also their areas of service, and increasing the diversity factor and the load factor.

For instance, Dr. Steinmetz mentions that electric trunk lines, "radiating from Niagara Falls, say, to Erie on one side, and to Syracuse on the other, meet a variation of one hour in time; so that, if you would supply all the energy of Erie and all the energy of Syracuse, and even if those cities had identically the same load curve, you would get a diversity factor due to the time difference," and of course a higher efficiency.

4. According to Dr. Steinmetz, the next step will be for the large concerns, generating electricity, to reach out and study, and in some way control, the electrical requirements of the manufacturing industries which they serve, in order better and more economically to adjust the demand to the supply.

5. But, we may now ask, "What then?" Does this not lead logically to a combination of all the industries, including that of the generation of electricity, under one great directing and controlling force, with resulting economies, at present hardly dreamed of? If so, it is inevitable.

Bellamy foresaw just this happening at just about this time; but he saw his vision a quarter-century ago; and it is perhaps not strange that, with the limited facilities then afforded, he could conceive of all this as going on, under exclusive and absolutely private control, such as then obtained, until, some fine morning, the nation should wake up and take the management into its own hands, presumably allowing the former magnates to remain in charge at liberal salaries; whereas we of today see the process of absorption of industries going on simultaneously with their growth.

A little observation must satisfy "the Young Engineer" that we have reached that stage of industrial and social development where the dominant feature is the subordination of the individual

to the community, the absorption of the small plant by the "trust," and that the tendency of things today is irresistibly toward the elimination of private, in favor of public, ownership and operation of all industries, as we have long had it in our municipally owned and operated water supply systems.

Thus, referring to coming "changes in our industrial and in our political condition," Dr. Steinmetz well says:

"Obviously, when electric power generation, transformation and distribution are as essential for the welfare of the country as are the freight and passenger transfer and distribution by our railway systems today, then it will no longer be permissible for any farmer or any village council to stop the electric transmission lines from being installed and operated. Before the Twentieth Century has advanced any considerable extent, we shall have a code of laws produced in accordance with the conditions of the Twentieth Century, and not a mixture of laws and rulings representing decisions from the time of Alfred the Great and William the Conqueror up to the days when the New Englanders burned their witches."

The fundamental thought suggested by Dr. Steinmetz's paper is that the day of small things has passed, that the near future is to see nation-wide activities, and that these cannot be controlled, with satisfaction to all, by individuals or by small groups of individuals taking their remuneration in the shape of profit. Nothing short of national control of all industry can satisfy the requirements of the next generation or two.

It behooves "the Young Engineer" to recognize that we are in the midst of the rapid formation of a vast and highly organized national industrial army; as incomparably superior, in efficiency, to the still largely unorganized mob of today, as the German army is superior to a horde of unorganized savages.

"The Young Engineer" will do well to shape his course accordingly.

GENERAL KNOWLEDGE, TECHNICAL TRAINING AND MANUAL SKILL

By L. J. LeConte

GENERAL EDUCATION

The courses of instruction taught at our standard universities are theoretically all right, embracing physics, chemistry, geology, applied mechanics and mathematics, ending up with trigonometry and analytical geometry. Calculus and the higher branches of mathematics can be omitted entirely. With this as a foundation, then structural and hydraulic engineering can be taken up and carefully studied. When the young man graduates and gets his diploma, he is literally full of book knowledge, but is entirely devoid of either experience or judgment.

Good judgment, exercised in any given case, is that invaluable quality of mind born of long experience. It cannot be acquired simply by reading books, for the simple reason that, as a general rule, busy men full of valuable experience do not write books, they have not the time or the inclination. The proper thing for the young man to do is to go into the office of a leading hydraulic engineer and there pick up and learn the practical side of his business, which is far more important to him than the mere theoretical side of his education which he acquired at the university.

In order to acquire this valuable knowledge he will probably be required to spend four or five years in this subordinate position; but when he comes out and opens an office of his own he feels much more confident and self-reliant and is well armed for the battle of life.

VOICE OF EXPERIENCE

The writer cannot close this brief without one or two cautionary remarks. Let the young man study his particular case in hand carefully in every detail, and if anything is doubtful make another survey until he is sure of his facts. Then when he comes to apply the usual formulae to his case just remember that all formulae are based on small scale experiments, and they are, therefore, only

applicable to a limited number of cases of nearly the same scale. When you come to applying the formulae to big cases, they no longer fit the case, and you are compelled to modify them accordingly.

DISCUSSION

PROF. B. L. SACKETT: In the western states the man who studies hydraulics takes up irrigation; if he goes south he goes into drainage; if he should take a position under the government on the Great Lakes, he is engaged in river and harbor work, or if he is in other lines of what we call hydraulic engineering in this or adjoining states, he goes into water power engineering and hydro-electric practice.

Now manifestly the employer should not forget that the engineering graduate has been a boy for four years, and is still practically a boy. A great many employers do forget that they were once boys themselves, with the limitation of boys, and they ask too much of a college graduate. It is entirely impossible in a four years' course, particularly if it includes paleontology and the other things, for him to get very much of the specialty of irrigation engineering, or of waterway improvement, or drainage, or hydro-electric practice.

He must, of course, acquire the fundamental principles or backbone of the thing; but as soon as we get beyond these fundamentals and into the details of a specialty the university is getting on dangerous ground.

The student needs to understand the fundamental principles, to know them for himself outside of the dicta of the professor. As soon as you get beyond these fundamentals in the laboratory up into the specialties, you are getting into the realm of empirical education. When you tell a young man that a horizontal wheel is the thing that he ought to use here, and a vertical wheel somewhere else, in hydro-electric work, or twin power, or quadruplex, or something else, it is largely empirical, and the tendency of it must be to take from him his own independence and make of him that thing that we do not want, a more or less dependent individual.

What we want is that technical education which gives him a firm grasp on himself and on the fundamental principles, so that he will feel as sure of his deductions as was James B. Eades when he said that given first a simple scientific principle the results should be infallible because when the principle was applied no mistake

could be made. If we keep before us simple fundamental principles, we are at least building on a sure foundation and keeping our feet on the ground. With that proviso the speaker confesses he is not so much concerned about the particular line of differentiation which the young man shall pursue during his four years' course. During the fourth year perhaps he specializes some; but it does not matter so much about whether his specializing takes the form of irrigation, or of hydro-electric practice, or of locks and dams and river control, so long as he be encouraged so far as he can to use his individuality, his judgment, his knowledge of these simple principles. The speaker says, "so far as he can," because the limitations are there and we must recognize their existence.

It is when he gets out into the field that he can go far into the specialty which he undertakes.

You must not forget that the boy of today, when he goes into hydraulic engineering after graduation, is entering upon a subject that calls for the exercise of rare judgment, and he has little experience upon which to ground that judgment; therefore the speaker does not believe in too great differentiation.

If the speaker properly understood Prof. Mead, he agrees with him distinctly that the graduate should have a knowledge of the fundamentals and the practical limitations which are imposed by the laboratory. He certainly should have been well drilled in the principles of hydraulics if he is to go into power lines, or, if he is to pursue water power construction, he should study the question of topography, geology and rainfall, because they are the fundamentals for lack of which so many failures have been made in connection with hydro-electric development.

This, too, leads to another suggestion, that in addition to what is usually included in the curriculum, the student should know something about finance. Very few boys have had any contact with business. They have had no occasion to direct their thoughts to the question of how an engineering undertaking is financed, or how to give its securities value. They do not know much about depreciation. To be sure they can not learn much of these things practically; but they should know something about methods of financing propositions so that they shall have an idea of the financial side underlying every project, because a man is not going to invest his money on an engineer's report, unless that engineer's report shows some prospect of financial returns.

Now concerning the college boy as a worker, the speaker is here in

his defense. To be sure, he smokes cigarettes and a pipe, a good deal for show, and a good deal of it by imitation; and undoubtedly of course we shall agree that it is not to his benefit but nevertheless, in spite of all these limitations, the college graduate on an average is as hard a worker, in hours per day, and as willing a worker as you will find anywhere. All those that have employed college graduates of the average quality will agree to that fact.

Only a matter of a couple of weeks ago certain information was desired. A college graduate got it inside of a limit of time in which only a college graduate would have gotten it, and by methods which he himself originated. He began working by early daylight to gather the information necessary under this investigation. The average man would not have done such a thing as that on the pay that he undertook it for, ordinary commercial pay, no fancy price.

And he is just as efficient a worker as you could expect from his years and his experience; and we must not expect too much.

There is still another thing to be said, that the young man from college on an average, besides his energy and ability, displayed where technical knowledge is desired, possesses certain other qualities of manhood which after all surpass his technical or his special ability.

The speaker feels from his own experience with the college graduate that he is on the whole a very reliable fellow, although sometimes ashamed to ask for information for fear of exhibiting his ignorance; but under the circumstances he is quite as reliable on the job and quite as persistent in getting at the thing which he believes is wanted, as the man who has spent four years in the practical work instead of in the university. He is reliable, and that certainly is one of the things that he must be. He is ambitious within reasonable limitations. He is not very egotistical; while at the same time he has some confidence in himself gained during his college course.

If he has gotten these fundamental principles of hydraulics, and laboratory experience sufficient to show their application; if he has a knowledge of his own limitations; if he is a good, clean, reliable fellow, and serious minded, there is not much fear, no matter what the particular specialty to which he may apply himself, but that he will show up fairly well if the employer will but remember that he was himself a boy once upon a time without the capacities of a man.

PROFESSOR THOMAS: Will Professor Waller give a little better explanation as to the matter of credits given for practical work done outside of the college?

PROF. O. L. WALLER: One illustration which will probably help us as much as anything. A freshman came into college and was classified. Two weeks after that the speaker met his father going across the street, and had an opportunity of talking with him for an hour or two. It was revealed that the young man had been employed in an engineering capacity for some two summers, the most of it being in railroad work. He had done plain surveying field work, and also field work in topography and a great deal of work in railroad location. We classified him, giving him credit for laboratory work, for field work and plain surveying and topography and such part of railroad work as he had done, and then held him accountable in the class lecture work for the theory that went with it.

PROF. WM. T. MAGRUDER: Mr. Chairman, we engineering educators were very desirous to hear from the hydraulic engineers who are in attendance at the Water Works Convention, and feel that we have learned much tonight from those who have spoken; but want to ask a few questions. Was it a college-bred man who put a four-inch plug on the end of a one and a half inch pipe? If so, could any human being have taught that man common sense? Is there an engineering college in the country which gives a course in common sense? Is there a Professor of Common Sense in any engineering institution in the world, including the Naval and Military Academies of our own country? In order to train a man in common sense, you need to begin with his grandmothers, if not earlier.

We have heard a great deal about what should be in the curriculum of the engineering college, and the speaker is very thankful to Professor Sackett for what he has said. We in the teaching branch of the engineering profession find it impossible to work ourselves or our students more than twenty-four hours a day, even in emergencies; and we find it impossible to be continually adding new studies to the curricula of our engineering colleges and yet remove nothing therefrom. Curricula have "yield-points" and can "break down," like other things. We would gladly turn out a more finished product, with twenty or more years of experience to its credit,

if we knew, or could be shown, how to do it in four years with the high school graduate.

JOHN W. ALVORD: The speaker is very glad to hear Professor Sackett in defense of the college graduate, because it seemed to him that the discussion to which we have listened has been slightly pessimistic. The college graduate is not an experienced engineer, and most of the trouble that the public experiences with the college graduate appears to come from over-estimating the value of his education.

The human mind is a very peculiar appliance. If it can be properly likened to any simple illustration, the speaker might say that it reminds him a good deal of a searchlight. You focus a searchlight on this object, and then on that object and if you have ever had, any of you, occasion to use a searchlight, you will have noticed how easily it darts from one part of the darkened landscape to another under a restless but untrained hand. Now a good many people go through college and also go through life jerking their mental searchlight around onto all sorts of various subjects, without any very clearly preconceived purpose as to what they want to find out around them. Other people use that searchlight more systematically, exploring the dark places, uncovering areas step by step, and systematically investigating the great darkened environment into which they are thrust and in which they exist.

Now the greatest value of college education is that it develops in a young man facility in guiding his mental searchlight; it gives him some idea of how to lay up step by step stores of knowledge which are useful to him.

We practicing engineers who take the product of the university are not looking for genius, we are looking for the plodders who can be thorough. We do not want great brilliancy; we want persistency, efficiency, thorough persistency. We realize that the young college graduate has not much perspective or a wide horizon but we know he has been trained to use his searchlight systematically, that if he is given a chance, guided by wise counsel, he will make good, and become a valuable member of society.

With these reservations, it seems to the speaker that we have excellent material in the average college graduate. Some fifteen or twenty years ago the college graduate came out rather self-sufficient, sometimes showing a tendency to instruct the boss; but that day has passed away, the evil was early seen. You rarely find the

college graduate coming out in that frame of mind which would make him feel that he ought to be in a few months on a high salary; he realizes his limitations. Sometimes he is even too timid, as Professor Sackett has said, in really getting his proper point of view and in really letting us know what he needs to know in order to be efficient in the new life which he enters.

The speaker believes in the engineering college graduate. He feels that they have in some respects a slow, patient and heart breaking job ahead of them, the introduction to any profession is a slow, patient and heart-breaking job for the young man; it is an uphill task requiring persistent effort. The young man has to build himself up little by little; if he build himself up solidly, it cannot be done quickly. The public instinctively will not accept the young man's judgment until he has piled up behind him in a more or less arbitrary fashion a sufficient number of years of experience. The public at large intuitively feel that years in a general way offer some guarantee that a man has acquired the common sense which is valuable, as well as a proper working knowledge of the physical and social laws of nature. And until that time comes the young professional man in any profession passes through transition which seems to him very slow and very, very heart breaking indeed sometimes. All this too comes at a critical period of his life when he wants and needs money. He perhaps desires to marry; he wants to establish himself. Yet there usually lie before him after college four, seven or ten years, as the case may be, of slow, patient work, which is in a large sense supplementary to his college education and in addition thereto, which must be gone through patiently and persistently, if he win an enduring grip on life. There are no short cuts that are worth following.

Of course, it is rather presumptuous for the speaker to talk to this gathering about college education, for personally he was unfortunate enough to escape the vicissitudes of a college education. He can only comfort himself by remembering the dialogue of certain well-known vaudeville entertainers, one of whom tells about his son "Heine" at college who is acquiring a great deal of useless inflammation and at last receives a diploma. "A diploma," he explains, "is a paper which you receive when you are through college, you frame it and hang it up on the wall, and then if anybody calls you a big fool you show him the diploma and that settles it."

But life is a college. The practicing engineer is never through

studying; and the great question is, have we the capacity to grasp the things around us which will educate and train us year by year throughout all our lives; and you will all, probably, agree with the speaker that the true object of college training and education is to furnish us an opportunity, before we begin active life, to learn, in some degree, to use the tools of life, the mind, the brain and the hand.

Mr. Dow R. Gwinn: There are a great many people who like to make fun of the college graduate, yet many of those who are so prolific with their jokes know very little about the experience that these graduates often go through. The speaker has in mind a graduate from Rose Polytechnic Institute, who graduated when he was twenty-one, in Civil Engineering. He came out about the time that the railroad companies were shutting off all their outside work, and it was not easy to get a position. We put him on our pay-roll at a moderate salary to do some drafting that we had, and he had rather a hard time of it for two years. This boy told me when he came out that he had not averaged over six hours' sleep for the last two years that he had been in college. He had been carrying two newspaper routes, one in the morning and one in the afternoon. His mother had worked in an overall factory to help support the family so that she could keep her boy in college; yet when he came out the future was not very bright for him. He had not received enough sleep to give him the proper rest, and the result was he was stunted in growth. It took about two years for him to regain his balance, and those first two years looked very discouraging; but at last he went to Canada and secured a good position with a railroad company where he is making good and has received two or three promotions in the last year.

Mr. W. W. DeBerard: The ability to add and the ability of adaptation are two points a young engineer should possess along with those theoretical and practical elements of hydraulics, for the teaching of which so many of our larger institutions are so admirably equipped. From the employers' standpoint, adding accurately is a priceless virtue in a young engineer's training, while for his own advancement, an engineer's ability to adapt himself to his surroundings is a characteristic that will carry him far on the road to success.

Adding accurately, and with addition is included the simpler

arithmetical calculations, makes an impression on the chief not to be belittled, for few engineers like to promote a new man who gets an average of a series of hydrographic readings nearly as high as the maximum. Misplacing a decimal point periodically after using a slide rule, because one is too stupid or lazy to roughly calculate the result, is likely to cause thoughts on the part of the employer of making the engineer's salary $9 instead of $90 per month. A mistake of a million dollars on a published estimate of the cost of a sewerage system of a large eastern city several years ago was detected just in time by the chief engineer who took the trouble to total the final summary. A recent report on city waste disposal in a city of the middle west is so full of similar errors, one reads the remainder of the report, if he has to, with distrust.

Along the line of adapting oneself to his surroundings and getting on with his fellow workers, one chief engineer always asks those referred to by applicants if he has the ability to fit into an organization and get along with his associates. To the speaker's knowledge, one young man, brighter and better equipped than the majority of young engineers, did not secure employment on an important piece of construction where valuable experience was to be obtained because it was his disposition to set everyone on edge.

Most of our senior year courses contain subjects the engineer may not be called upon to use for many years, if ever. It is common among the old school engineers to carp at placing these courses in the curriculum and they often express the opinion that the present day graduates come out of school with the idea of telling the chief how to carry on his work. Much of the early work of the young engineer will be plodding, tedious routine of endless calculations, mapping, hydrographic gagings or surveying. If he can adapt himself to this work the more easily by knowing something of what it is all about and how the problem is being solved in a big, general way, the berated senior courses have certainly served one admirable purpose.

Picture a camp in a 100-square mile area of flat country where mirages of beautiful lakes rise on every hand and dancing heat waves make a leveling rod look like a coiled snake standing on its tail. Orders are to occupy every corner of 500 x 1000 feet rectangles and take "shots" at the corners of approximately 100-foot squares because a ½-foot contour map for irrigation purposes must be made. Specific features of education, knowledge or training will have little to do with the success of the young man here. Only

natural or acquired enthusiasm, ability to get on with his fellows and adapting his stomach to the Chinese cook's fare as well as to his chief's disposition will carry a man through.

Given the fundamentals, the successful engineer must then proceed to acquire experience, for engineering has been defined as nine-tenths experience and horse sense, and one-tenth theory. This varied experience can rarely be obtained under one employer, but an opportune time for him to change must be sought with tact and without embarrassing the chief, and sometimes without regard to immediate salary increase. To make the topographical map of his brain complete, interesting and valuable to the owner and to others, the hydraulic engineer must occupy in succession first, those stations in the monotonous plains of plodding drudgery with its mirages of possible prosperity, later those stations on the rolling rounded hills of the $100 to $150 assistant engineer's position where the multitudes thrive, fight, are held or are content to gaze on the fascinating mountain topography of the consulting engineers; finally to occupy the promised land of opportunity and originality, with its closely drawn contours of rapid rises and equally steep declivities, leading finally to that broad plateau where grand conceptions coupled with heroic endeavors are molded into the admiring world's most marvelous structures.

CHARGES FOR PUBLIC WATER SERVICE TO PRIVATE FIRE PROTECTION SYSTEMS

By W. E. Miller

In the formation or readjuctment of the schedule of rates of a water utility which furnishes service to private fire protection systems in its territory, the question as to how much of the utility's revenue should be derived from that class of service becomes a subject for serious consideration. In a slightly different form it became one of the leading topics of discussion at the thirty-second annual convention of this association held at Louisville in June, 1912, by having been involved, to some extent, in questions 6 and 7 in the query box. It has apparently been a more or less vexatious subject in water works circles for many years. It has been involved in cases in the courts and has had to be passed upon judicially. The same question is involved in the rate case of the Milwaukee Water Works, now pending before the Railroad Commission of Wisconsin. There has already been so much discussion of it in the past that it is difficult if not impossible to present any entirely new considerations in reference to the subject, hence the writer's present object is merely to summarize, review and discuss the several arguments for and against the establishment of schedule charges for service of this kind. This will be done with particular reference to such special conditions as exist in Milwaukee.

The Milwaukee Water Works now has about 150 connections of its mains with private fire protection systems. Many of these are for automatic sprinkler service, others serve risers or standpipes having convenient fire hose connections and probably some are for service to private yard hydrants. Some of those first installed are of 6-inch diameter but all of the more recently made connections are of the 4-inch size. The water department no longer permits branch connections larger than 4 inches in diameter to be made, but it allows two of that size to supply a 6-inch private line. All have been made at the expense of the property owners served, so that the department has no property the investment in which is chargeable wholly to this class of service. The city has heretofore been furnishing

unmetered fire service through these connections free of charge, yet one of the department's rules (not enforced) provides that "all branches used for fire purposes must be controlled by a meter approved by the Board of Public Works." It is further provided, that the installation of the meter is to be made by, or at the expense of, the property owner in each instance.

After having made and submitted a tentative valuation of the physical property of the Milwaukee Water Works, the engineering department of the railroad commission was instructed to apportion the value between public and private service. The former class included the general fire protection and municipal sewer flushing, in other words, the municipal hydrant service. The latter includes all other municipal as well as domestic and industrial service. The commission further called for a subdivision of the value apportioned to public service, the subdivision being between municipal hydrant service and private fire protection. The commission, therefore, sought to know the amount of the investment in the property of the utility to be supported by revenue which may hereafter be received for the furnishing of private fire protection. This involved the preparation of a report covering the following underlying and related questions:

1. What is the effect of private fire service connections upon the necessary facilities of the utility?

2. Is private fire service fairly chargeable with the support of any part of the plant investment?

3. If question 2 be answered affirmatively, upon what basis is the amount of the investment so to be supported to be measured?

The report covered also the method of making the primary apportionment of the value of the property between public and private service. Briefly stated, that method was to apportion the value of each feature of the property on the basis of the estimated relative costs of corresponding features of hypothetical separate plants. In this connection it was shown that the reasonable maximum demand which a public service plant should at present be capable of meeting was a rate of at least 10,000 gallons per minute or about 15,000,000 gallons per twenty-four hours in the districts of greatest hazard, while that for private service should, for the present, be about 70,000 gallons per minute or 100,000,000 gallons per day, distributed over the entire city. The result of the application of the method was the following final summary of the apportionment of the value of the property.

FINAL SUMMARY

Joint Engineering Dept. Sheet No.....
Wis. Tax & R. R. Commissions Valuation as of June 30, 1911
Company Milwaukee Water Works Date Compiled January 20, 1913
Location Milwaukee, Wisconsin Compiled by WJF
Checked by RLF

Apportionment

	PRIVATE		PUBLIC		TOTAL	
	Cost New	Pres. Val.	Cost New	Pres. Val.	Cost New	Pres. Val.
A. Land	$773,245	$773,245	$95,315	$95,315	$868,560	$868,560
B. Trans & Distribution	3,045,476	2,991,310	1,735,645	1,695,169	4,781,121	4,686,479
C. Buildings & Misc. Struc.	309,175	242,107	42,580	30,481	351,755	272,588
D. Plant Equipment	580,184	366,810	136,093	86,042	716,277	452,852
E. General Equipment	9,999	5,758	2,933	1,511	12,932	7,269
[1]*F.* Paving						
Total	$4,718,079	$4,379,230	$2,012,566	$1,908,518	$6,730,645	$6,287,748
Add 12% (See Note Below)	566,169	525,508	241,508	229,022	807,677	754,530
Total	$5,284,248	$4,904,738	$2,254,074	$2,137,540	$7,538,322	$7,042,278
H. Material & Supplies	68,098	68,098	38,990	38,990	107,088	107,088
Total	$5,352,346	$4,972,836	$2,293,064	$2,176,530	$7,645,410	$7,149,366
J. Non Operating					73,559	52,013
Total	$5,352,346	$4,972,836	$2,293,064	$2,176,530	$7,718,969	$7,201,379

NOTE: Addition of 12% to cover engineering, superintendence, interest during construction, contingencies, etc

Percentages (exclusive of non-operating)	69.5%	30.5%	100%

[1] To be considered in supplementary statement.

Returning again to question 1 above, let us consider what is the effect of private fire service connections upon the necessary facilities of the utility. It has been urged that such connections endanger the general fire service of the community through the possibility or even probability of wrecking and breaking of private pipe lines during fires, in which case the utility finds it impossible to keep up the necessary pressure at surrounding hydrants. Cases of the kind are reported to have occurred in other cities, though none as yet in Milwaukee. In some of these, disaster resulted from inability to control the supply of water flowing freely through the broken piping, owing to lack of proper gate valves or to the fact that they had been provided but set in places which became inaccessible during the fires. It is reported that the practice in some cities is to place the controlling valve just outside the building, and that sad experiences have shown the lack of wisdom in such practice.

In Milwaukee the valves are adjacent to the water main in the street where they are in but little danger of becoming inaccessible during fires.

Another very important reason why the general fire protection service in Milwaukee is believed not to be endangered by the possibility of broken piping of private fire lines lies in the fact that the water works does not attempt, at any fire, to maintain any considerable pressure at neighboring hydrants and furnish hose streams directly therefrom. All fire streams from the city mains are supplied by steam fire engines. The city pumping stations do not even receive notice of a fire alarm and of course do not make any increase in pressure above that regularly furnished. When a number of engines are drawing heavily from the group of hydrants surrounding a fire, or from cisterns in the same vicinity supplied by the water mains, the water pressure at a broken private fire service connection will, especially if the mains in the locality be comparatively small, be thereby so much reduced below normal as to materially reduce the flow and waste through such break. So long as water does escape in that way it must, in general, pass the points of draft of the engines and represent an excess of supply above the requirements of the engines.

These and other conditions make it appear that there is but very little, if any, danger that the general service in Milwaukee may be seriously crippled by breaking of private fire lines. A competent water works employe responds to all second and third fire alarms to coöperate with the fire department in the manipulation or use of valves, hydrants or other water works equipment. It is his duty to close the valves or connections to private systems upon instructions from officers of the fire department. It seems that we are compelled to regard connections between the city mains and private fire systems in Milwaukee as a means of making quicker and more efficient use of the water service which would otherwise be supplied only through hydrants and steam fire engines rather than to regard them as a possible menace to the general service. The writer finds no basis for considering that such connections create any greater demand upon the utility in this case than would exist without them. The facilities of the utility which are necessary to meet the requirements of the general fire service are, therefore, apparently unaffected by private fire service. If this be true it would seem that the apportionment to this class of service of a part of the investment in the property of the utility can be made only on an arbitrary basis.

COST OF FURNISHING THE SERVICE

A careful reading of the several decisions of the Railroad Commission of Wisconsin in public utility rate cases leads strongly to the idea that the schedules of charges prescribed therein are based almost entirely upon the ascertained cost of furnishing the service, rather than upon its value to parties served. The commission has repeatedly stated that every utility is entitled to earn its legitimate operating expenses, including depreciation and taxes, and also a fair and reasonable rate of return upon the value of its property. Insofar as either the legitimate operating expenses or fixed charges of any utility are definite amounts at any period of its history or development, it would appear that when a third general class of service enters into consideration and is made to bear a share of the general expenses by apportioning them upon either a logical or arbitrary basis, the other two classes are to be relieved of the amounts so charged to the third class and benefited by a reduction of rates somewhat below what they would otherwise be. Insofar as the gross amount to be earned by a utility is definite, it is not easy to see that the utility itself is necessarily to be much concerned whether the earnings are to come from two classes or three. The consumers in the three classes appear to have far more concern in the matter.

If it be granted that the recipients of water service for private fire protection are not to be required to contribute to the fixed charges of the plant owing to an absence of any but an arbitrary basis of division thereof, we arrive at the subject of the operating expenses. It is often argued that private fire protection systems are installed for the sole purpose of reducing cost of insurance and therefore of economizing in annual expenses of the property owner. This saving is effected, however, by the making of a considerable investment, which means increased charges for interest and depreciation, thereby offsetting some of the apparent saving. The granting, by fire insurance companies, of large reductions in premiums is an unquestionable testimonial of the greater efficiency of private over public fire protection. Greater efficiency in this case does not mean that the same work or the same quantity of water accomplishes greater results, for there is only one result to be accomplished, namely to quench the fire. It means that less water is required to accomplish the desired result. The supplying of less water means the burning of less fuel for driving the water

works pumps and consequently the furnishing of private fire protection effects a direct, though perhaps small, saving to the utility from the cost of furnishing only public fire protection service.

So far as pumping expense alone for actual fire fighting is concerned it does not appear reasonable to assess any part thereof to a class of service which is a distinct advantage to the utility in reducing its expenses. But experience has conclusively shown that unless it be metered, the service is likely to be misused and abused in many cases. Although the rules of the insurance companies forbid the use of private fire systems for general water service, and in fact stipulate that they are to be used for no purpose other than fire fighting, the rules are not effective unless rigidly enforced and are supplemented by close inspections and tests. Numerous instances in which large quantities of water have been surreptitiously used daily through secret connections to the private fire systems are reported to have been discovered by water works officials in various cities; the water thus obtained from the public supply mains represents a loss to the utility of revenue which should have been, but was not, obtained.

In the light of experience, unmetered public water service to private fire protection systems must be regarded as distinctly involving a special expense to the utility. The expense may be either in the cost of pumping water which is afterward stolen from the system by dishonest citizens or it may be in the cost of maintaining an adequate system of inspections and tests to detect and stop such abuses.

Metered service of the same class is apparently free from both elements of cost. The consumer's meter, controlled by the water department, becomes the department's inspector, working continuously without pay, and presumably determines, within narrow limits of accuracy, the amount of water used. The revenue due the utility therefor can readily be computed and collected, at no greater expense in general than in billing and collecting from any other consumer.

VALUE OF SERVICE

That the service furnished by a public water works through connections to private fire lines is distinctly of value to the party served has never, so far as the writer knows, been denied. It is upon the basis of the value of the service that the strongest claim for revenue is made by the management of water plants. This basis of charges has received the consideration of and has been used to a limited

extent by the Railroad Commission of Wisconsin but it has apparently been given greater weight in railroad rate cases than in those involving public utilities. The extent of the use by the commission of this basis of charges appears to have been a mere modification, for the sake of expediency, of the charges determined on the basis of actual cost. It is apparently upon this basis alone that courts have already held, and may in future cases continue to hold, that the recipients of private fire protection service should furnish a part of the utility's revenue by the payment of schedule rates.

The service may be of value to the party served in that it may form one of two required sources of water supply to the premises in question. A condition precedent to the granting, by insurance companies, of the maximum reduction in insurance rates for the added security of automatic sprinkler service is that the facilities shall include two separate sources of water supply, one of which may be the city mains. The other may be a suitable tank properly elevated to furnish adequate pressure and filled from the city mains; or it may be a private pumping plant drawing its water from a stream, lake, reservoir or an adequate well. The city water service, however, apparently is not recognized as one acceptable source of supply for automatic sprinkler systems unless the minimum pressure regularly maintained in the mains of that vicinity is suitable for effective operation of the highest line of sprinklers in the building. It will, therefore, be evident that the value of city water service for private fire protection, from the standpoint of a property owner, will depend upon the height of his building and the ordinary pressure in the city system in his vicinity.

There are some instances where the ordinary city water pressure in Milwaukee is inadequate for automatic sprinkler service in the upper stories of the buildings. In these cases the branch connections from the public mains are for the purpose of supplying water to private pumping plants which are arranged to either deliver the water into elevated tanks or to furnish direct pressure should the tanks be out of commission. In these cases the yearly value of the private fire service furnished by the water utility would seem to be measured, or measurable, by the interest and depreciation on the investment required to obtain an alternate supply of water for the private pumping plant. In the cases of industries along the rivers a small investment would provide an inexhaustible supply for the private fire pumps and the value of the city supply would be rendered quite small.

There are other cases in Milwaukee, wherein the value to the property owner of the private fire service of the city water works is much greater than in those contemplated above. The diversity of conditions found in different cases in the city of Milwaukee introduces great difficulties in the way of establishing schedule charges for private fire protection service on the basis of its value to the property owner.

While this class of service has a greater or lesser value to the property owner, it is equally clear that it has some value to the water utility and to the public in general. The interest in private fire protection, which is universally recognized as more efficient fire protection, is mutual.

The interest of the water utility is, perhaps primarily, in the reduction of the number of bad fires of long duration to be fought, but it is also interested in the continued prosperity of its patrons, which means the prevention of destruction, by fire, of industries and the consequent throwing out of employment of large numbers of workmen, many of whom are patrons of the utility.

The city at large is interested in the preservation and prosperity of its industries, the continued employment of its people and in the protection of property and human life. The public is interested greatly in insurance rates or cost of carrying fire insurance. Since insurance rates are so largely dependent upon the fire losses and these are in turn dependent on the efficiency of fire-fighting equipment, the public as well as the individual property owner is financially interested in the installation of better fire protection facilities in the establishments of large value.

The courts have said in certain cases that the interest of the water utility and the public in the installation of private fire-fighting systems is secondary and incidental and that of the property owner is primary and of such moment as to justify a charge for water service thereto. But it appears to the writer that such opinion results from an overestimate of its value, to the individual, of the water service and an underestimate of its value to the utility and to the public. The value of private fire protection systems, especially automatic sprinkler systems, in the protection of human life can scarcely be expressed in dollars and cents.

It appears proper to mention, also, the fact, as reported, that the plan of requiring, by municipal ordinances, the protection of certain classes of property by automatic sprinkler systems has been extensively agitated. The city of Chicago already requires its

theatres to be protected from fire by automatic sprinklers and is now (January, 1913) reported to be considering an ordinance extending the requirement to other classes of property. This is in the interest of public safety. The writer firmly believes that the time is soon coming when all of our leading cities will have such requirements in force.

The enactment of ordinances imposing upon property owners a duty of providing expensive private fire apparatus carries with it a moral obligation on the part of the city to furnish water to that apparatus instead of withholding it for use only through city hydrants and fire department service. The water should be furnished inside the premises at no greater cost to the property owner therefor than if supplied from hydrants. The service from hydrants is presumably paid for by the property owner as a part of his general property taxes. He should be entitled, without extra charge, to make more efficient use of that same service.

In a paper read at the Denver Convention of the International Association of Fire Engineers, in September, 1912, it was shown that apparently a large majority of municipal water plants of this country, and a considerable proportion of the privately owned works, already furnished service to private fire line systems either entirely without special charge or at a very small charge. The cost to the utility of furnishing such service is apparently, in many cases, held to be covered in the revenue commonly called hydrant rental.

There is one condition now existing, as the writer believes, only in Wisconsin, which is of such interest and importance in this connection as to deserve attention at this time. This arises from the passage, and the provisions, of the Wisconsin Public Utilities Law, under which the railroad commission is empowered to equitably divide the total expenses of a water plant between public and private service. It was found that several Wisconsin water utilities, and it is believed that many such utilities in other states, have not received a fair share of their revenues from the public in return for the hydrant service furnished. When the so called hydrant rentals are made to cover a better share of the fixed charges and operating expenses of a water works and all of such expenses are provided for in the rates and earnings, the utility has less necessity of endeavoring to increase its earnings by charging separately for private fire protection.

In the case of the City of Beloit v. Beloit Water, Gas and Electric Company, 7 W. R. C. R., 187, the commission held that the city

should pay an increased charge for fire protection and that the payment should cover all fire protection, including that formerly furnished by the company, at a special charge, to private hydrants in the yards of certain industrial plants.

In view of all the considerations in the matter, most of which have been considered above, but perhaps with less fullness in some cases than might have been proper, the writer has reached the conclusion that the Milwaukee Water Works should continue to furnish service to private fire systems free of special charge, provided it be metered, as provided in the department rules.

There are two other important questions related to the foregoing and concerning which some comment may here be in order. The first of these is that of size of pipe used for the branch connection from the street mains. The conclusion reached on the question of charges for service to private fire systems was irrespective of the size of the connection. Had it been, or should it be, found that a charge should be made for service through any given size of connection it would be easy to establish the justice of varying the charge with the size of pipe. Due to the existence of some 6-inch connections made prior to the Milwaukee Water Department's adoption, some years ago, of the rule limiting the size of openings made thereafter from the mains to a maximum diameter of 4 inches, this rate case might have involved and may possibly yet involve, the determination of the difference in charges for service through branches of those sizes. But so long as the department's rule stands unquestioned and so long as the foregoing conclusion as to charges for private fire service is accepted, the other question concerning variation in charges is eliminated from the case.

The other of the two related matters is the danger of pollution of the water in the city mains by the leakage, through defective check valves, of water from private fire systems which are ordinarily and normally kept filled under higher pressure, with water from an independent and badly polluted source. There have been a number of cases in Milwaukee where such danger existed, and the water superintendent reports having found evidence that much foul water has entered the city mains in that way. Some of primary supplies of the private fire systems are taken from the Milwaukee, Kinnickinnic, and Menomonee Rivers, all of which receive a great deal of sewage. The connections for city water service to such private systems are for the purpose of providing the secondary or alternate water supply required by the underwriters. The depart-

ment in this case recently adopted the plan of requiring the private fire pumps which normally draw from the rivers, to be closed down and have the gate valves on their discharge lines closed and sealed, except when operating for actual fire service. The danger can very readily be cared for and probably wholly eliminated. It is certainly a matter of very great importance and demands effective supervision.

It will be seen that, in the writer's judgment, the public water service to private fire protection systems should, in general, be covered by or included in the charges for public hydrant service. There may, however, be cases in which this cannot properly be done or should not be done, so that while his belief in the principle is strong, he is not yet prepared to claim that it should have universal application.

PRIVATE FIRE PROTECTION SERVICE CHARGES

By Leonard Metcalf

In response to the request of certain members of this association that the investigations, which culminated in the presentation, two years ago, of a paper by Messrs. Kuichling, Hawley and the writer, upon "Some Fundamental Considerations in the Determination of a Reasonable Return for Public Fire Hydrant Service," be extended to cover the field of charges for private fire protection service, the writer comes before you today, to present the results of his inquiry into current practice in this country in relation to charges for private fire protection, with a statement of the principles underlying such charges.

The results of the circular inquiry were discouraging, but 370 replies being received to upwards of 2500 circulars sent out. If the replies received may fairly be assumed to be characteristic of present practice in the matter of making charge for private fire protection service, the practice is as variable and as illogical as has been that in the making of public fire protection charges. It may be of advantage, therefore, to discuss, *first*, the general principles underlying this subject; *second*, the results of the circular inquiry; *third*, the conclusion reached by the more conservative fire insurance engineers as to service required; and *fourth*, to outline tentative conclusions.

UNITY OF INTEREST

The subject is approached from the point of view that fundamentally the interests of the community, the waterworks superintendent, and the insurance companies, are identical. The old days of willingness upon the part of insurance agents to have bad fires on account of the large premiums and commissions involved by them, if they ever existed to any considerable extent, are happily past. That there has been serious and unnecessary friction between insurance agents and waterworks men is of course true, but this has most often been due to the fact that technical matters, which should have been passed upon by engineers rather than by business men, were left

by the insurance companies for decision by inexperienced agents, rather than by men technically trained in this field. With the coming of the factories mutual companies and a juster recognition of the importance of the engineering factors involved, there has been developed a small band of engineers to whom has been intrusted the study of these technical questions, independent of the question of insurance rates. It seems likely and is certainly to be hoped, that the next step taken by the insurance companies along this line will involve the reference of rating problems to these, or other engineers trained in this field, that underlying principles may be standardized the country over, along the line of fundamental equity, rather than commercial exigency as has so often happened in the past.

The members of this association may therefore well cooperate in the fullest measure with the insurance engineers, and it is to be hoped that the subject may be approached in a judicial spirit with full recognition of the difficulties with which it is beset, as seen from the one and the other point of view.

It is assumed that the needs of the community, in the matter of adequate fire protection service, are paramount to the needs of the individual manufacturing, or commercial, interest. Within this limitation and that of the available financial resources, it is assumed that the individual manufacturing establishment, commercial house, or citizen, should be given the best possible service.

PRIVATE FIRE PROTECTION SERVICE DEFINED.

The term "private fire protection service" is here used to cover water service furnished by the waterworks to manufacturing establishments, commercial houses and individuals, for use upon their own premises as a means of preventing fire, of limiting its spread and of fighting it, in contradistinction to the public fire protection service. The latter covers the placing of hydrants upon the water service mains, the maintenance of reservoirs, pumping stations, pipe systems and fire hydrants for use solely for firefighting, and the maintenance of fire departments with chemical engines, hose carriages and other protective apparatus.

The construction of independent high pressure fire protection systems is a special problem, likely to be limited only to the largest communities, for it carries with it heavy cost and dangers of its own.

In private fire protection service insurance men are agreed that the internal pipe distribution system, suspended from the ceilings,

equipped with sprinklers which open automatically when a certain temperature is reached, constitutes the most important element, and it has been asserted that the time is not far distant when this system would be introduced in practically all commercial buildings and manufacturing establishments of magnitude. In addition to the sprinkler systems within the building, private hydrants and standpipes, with hose connections without and within the buildings, are also used.

CHARACTER OF RISK

In discussing the question as to what constitutes adequate fire protection service, the difference in character of fire risks must be clearly borne in mind, not alone as to the hazard of the type of building and contents, but more important yet, its location and environment. Thus the nature of the problem is quite different in the heart of the congested value district, with high buildings, closely built up areas and reasonably fireproof construction; in the general business district, with moderately high buildings and slow burning, if not fireproof construction; in the residential districts with well separated houses; and in the well isolated plants, constituting independent units.

The corresponding differences in pipe system are also to be borne in mind, the congested value district with its gridiron of pipes of fairly large diameter, fed by main arteries; the general business district, perhaps somewhat less well served; the residential district with gridiron of smaller pipes and occasional main arteries; the isolated plants or districts with long lines of feeders of less ample dimensions and without the advantage of reinforcement by a general gridiron system. This matter is of particular importance in the consideration of the maintenance of pressure as well as volume of water under fire draft, and the danger to the community as a whole from broken connections or services.

WHAT CONSTITUTES ADEQUATE FIRE PROTECTION SERVICE FOR THE INDUSTRIAL ESTABLISHMENT?

For the hydrants a pressure of 75 pounds or more at the hydrant is desirable in order that a pressure of 40 pounds or more may be maintained at the nozzle, with a discharge of from 200 to 250 gallons of water per minute from each nozzle. The location of the hydrants and the feeding pipe system will depend upon circumstances and

is at issue for the most part in isolated risks, rather than in those located within the thickly built up portion of the city, where the public hydrants serve the risk, except insofar as the standpipe with hydrant connection may be used in the latter.

A prominent fire insurance engineer has stated:

> An automatic sprinkler in an equipment usually discharges 15 gallons per minute, and it is not unusual to have 50 sprinklers opened by a fire, thus requiring 750 gallons of water per minute. To accomplish this delivery, there should be a pressure of at least 15 pounds on the highest line of sprinklers *while the water is flowing*. These figures may be taken as a minimum necessity for the plant of ordinary size and as indicating the amount needed in addition to the supply for hydrants, but for large properties of combustible occupancy, and large area between fire walls, double this amount of water is often found desirable and available for sprinklers. In some large industrial establishments the protection is so laid out that several thousand gallons of water has been provided as a primary supply.
>
> A characteristic of good sprinkling protection is its ability to control a quick, snappy fire, which perhaps spreading over a considerable area, is also burning in or under material where it cannot be reached by water from the sprinklers. Under these conditions, a large amount of heat is generated, which opens more sprinklers, which, if the water pressure and supply is maintained, completely surrounds the fire and prevents its further progress. It should be noted, on the other hand, that if pressure and supply are inadequately maintained as increased volume is demanded by the additional sprinklers opened, the fire will not be confined and more serious results will follow.

VOLUME AND PRESSURE OF WATER

Two essential factors are involved in good water service, volume, and pressure under different rates of draft. It is in the latter element, pressure, that disagreement has generally come between the insurance agent and the waterworks superintendent. Agents have often assumed arbitrarily that a pipe of given diameter was necessary, regardless of the available pressure at the point of delivery and the character of the supply and pipe system back of the service.

It is obvious that every private fire protection service is a special problem requiring a determination of these two essential factors,—the volume and pressure of water necessary and available at the point under consideration,—and it is clear that in view of the necessarily variable character of the conditions surrounding the water works and the fire risk, it is difficult to lay down general rules, though it seems likely that standards of practice will be gradually developed through the coöperation of water works engineers with fire insurance engineers.

Between the extreme demand of the radical insurance agent, for the largest possible volume of water under the greatest possible

head for the service of any special risk, and the anxiety of the water works superintendent, deeply sensible of his responsibility to the community at large to maintain a service, unimpaired by broken service, hydrants or open sprinklers, to keep the diameter of the pipe connections as small as practicable, there is a twilight zone within which arbitrary standards should give way to a fair minded interpretation by the trained engineer of the relative hazard involved and the most desirable course to pursue.

DANGERS INVOLVED AND SUGGESTED REMEDIES

Insurance men in the past have desired the largest possible connection with the city mains for private fire protection service. A juster recognition of the danger resulting from broken service headers or risers, standpipes, hydrants, or distribution pipe systems, has been evident of late and today some of our most conservative fire insurance engineers are advocating the limiting of private fire protection services to pipes not over 6 inches, and some even to 4 inches in diameter, in risks in congested value, closely-built-up districts, provided some latitude be allowed for special cases where pipes of somewhat larger diameter seem clearly permissible. It is urged that the use of several service pipes 4 inches in diameter, with the sprinkler system divided into units, is safer practice than the use of one pipe of equivalent capacity, except perhaps in the case of isolated risks. With this point of view water works men are in general accord, though some believe that there are cases in which a properly connected single pipe of 6-inch, rather than 4-inch diameter, may be preferable to a multiplicity of connections, and that the character of the pipe gridiron, width of streets and obstructions in them, adjacent to the risk, have an important bearing upon the problems.

In the case of the isolated risk, at the end of long pipe lines, the objection to the use of a service connection of more than 4-inch diameter is less serious, and often necessary, if a service equal to that available in the heart of the city is to be furnished.

Many cases of serious financial loss resulting from broken service connections, hydrants, risers or open sprinklers, have occurred, but even so they are probably insignificant in number and resulting loss, by contrast with the actual saving due to the more general introduction of the sprinkling system of fire protection. While taking every proper precaution to preserve the integrity of the

service, and its appurtenances, it is to the interest of the community to give the best possible sprinkler service to the fire risks.

To limit the pipe diameter arbitrarily to 4 inches, regardless of attendant circumstances, would result in giving an impaired, if not inferior fire protection service in certain cases, for loss in pressure due to friction in gate and check valves and in comparatively short pipe lines and bends in the service, with a 4-inch pipe discharging 750 gallons per minute, may well amount to 25 pounds or more, while with a 6-inch pipe the loss would be a little over one eighth of this amount. In a large plant requiring 1500 gallons per minute the loss in pressure in 100 feet in 6-inch pipe would be 15 pounds more or less, and 8-inch pipe about 3 pounds. This practically means that to arbitrarily limit the maximum pipe diameter to 4-inch is to limit the discharge of this unit of service to 750 gallons per minute or less, under the particular conditions of the service in question.

The danger resulting from broken services or appurtenances upon them, may be controlled in some measure at least, *first* by placing valves upon the street mains upon both sides of the service at short distances from the service in order to limit the portion of the pipe system which would be thrown out of service, should it become necessary to close these valves, to prevent bleeding of the main by broken services, or open interior hydrants, or sprinklers; *second*, by placing valves upon the service itself at a sufficient distance from the risk and sufficiently protected to make it possible to operate them in spite of fire in the protected building.

Another danger sometimes encountered is that resulting from the requirement of the insurance company of duplicate source of supply in cases where this duplicate supply is of a polluted character. Under these circumstances if the check valves located upon the city service fail to operate properly and the polluted supply be pumped into the pipe system at a pressure greater than that maintained by the city in its pipe system, there will be danger of the passage of the polluted water into the city supply. This danger is a real one and if the pollution is gross, the two systems should be quite independent of one another. On the other hand, there are many cases where the conditions are such that the danger can be controlled, with reasonable safety to the public by the use of duplicate check valves with suitable facilities for testing their tightness from time to time and proper regulations respecting precautions to be taken when testing the fire protection system, and with suitable provision for

periodic inspection. This is particularly true where the pressure at which the public supply is furnished exceeds at all times the private service.

SERVICE FOR FIRE PROTECTION SHOULD BE INDEPENDENT OF COMMERCIAL USE OF WATER

Insurance engineers, as well as water works men, are agreed today that it is desirable to make the fire protection service in a protected risk absolutely independent of the distribution pipe system installed for the industrial or general use of the water within the protected property.

USE OF METER UPON FIRE PROTECTION SERVICE

With existing frailties of human nature, and in the light of past experiences in many cases, water works men contend that a complete separation of the pipe system for fire protection from that for industrial use of the water, is not sufficient to prevent the use, surreptitiously or otherwise, of water from the fire protection service, nor does it prevent leakage in the pipe systems in mill yards, which is unfortunately all too common in many cases. The unauthorized use or stealing of water has been detected repeatedly, and in some cases men have gone so far as to manipulate gauges and remove or "doctor" the valves in the mill fire pump so as to permit the water to flow back through it, from the public supply into the mill system.

Several methods have been used for meeting this difficulty or abuse: *first*, the use of seals upon all connections; *second*, the installation of gated bypasses with meters upon them for occasional inspection; *third*, the occasional use of the pitometer for measuring the flow in these pipe lines; *fourth*, detector meters and similar devices embodying a check valve upon the main service, with small meter upon a bypass upon which to measure the small use of water and equipped with some differential device or meter to make possible, estimate of the quantity of water flowing through the pipe lines at such times as the main check valve may be unseated. In extreme cases clearly only a device like the detector meter, coupled with frequent inspection, will expose the dishonest practice. Happily, these extreme cases are not common in any one community.

Insurance men object to the use of meters upon the fire protection service on account of their obstruction to flow and the consequent loss due to friction, and on account of the danger of clogging or obstruction in case of breakage of the meter under heavy draft during

fire. The use of fish traps before the meters is even more objectionable.

The more liberal insurance engineers today regard the use of such devices as the detector meter, in part as a commercial problem, and in part as a necessary evil in many cases. In the small plant the burden of the installation of a detector meter may defeat the introduction of much desired fire protection service, where upon the larger service no such objection could or would be urged. Unfortunately the devices now upon the market are expensive from the point of view of the small manufacturing or commercial risk and for this reason alone, with its consequent effect in discouraging the more general introduction of private fire protection service in small risks, this association should be guarded in any action which it might otherwise take with regard to the general use of meters upon fire protection services.

COST OF INSTALLING PRIVATE FIRE PROTECTION SERVICE AND SAVING IN INSURANCE

It is extremely difficult to get specific information concerning the cost of installing fire protection equipments and the saving in insurance which results and therefore to generalize upon these subjects. The following figures are submitted with some diffidence and merely as indicating in a general way the cost of certain classes of such services.

1. A cotton mill having a value in buildings and machinery as follows:

Buildings, including foundations	$400,000
Machinery, engines, boilers, shafting, electrical and steam fittings, elevators, etc	900,000
Cost of mill	$1,300,000

Cost of Fire Protection Equipment for this Mill:

Underground piping	$2,600
Indicator post gates, valves, check valves, hydrants, etc	1,000
Fire pumps (2)	2,500
Suction supplies	1,000
Hose, hose houses, watchman's system and fire alarm	1,700
Automatic sprinklers and all inside piping	16,000
	$24,800
If suction reservoir has to be built, add	$3,000
Total cost of Fire Protection Equipment	$27,800

This is equivalent to *2.1 per cent* of cost of buildings and machinery.

2: A Smaller Plant, where cost of protection is of necessity larger in proportion to cost of mill equipment:

Buildings, excluding foundations	$70,000
Machinery, etc., same as above	100,000
	$170,000
Cost of fire protection, as items above	$6,200

This is equivalent to 3.7 per cent of cost of the buildings and machinery.

In these examples, if elevated tanks or reservoirs had been necessary, the fire protection would have been increased in cost correspondingly. They represent, however, fairly typical cases, but often times difficult conditions add to the estimated cost further amounts from 15 per cent to 20 per cent.

In general the cost of the fire protection equipment will be from 3 to 5 per cent of the cost of the mill property.

The operating charges upon such an installation as that cited in the first illustration given above might be as follows:

Interest	6 per cent
Depreciation	2 per cent
Repairs	3 per cent
Supplies and Miscellaneous	1½ per cent
Coal for use on Sundays and Holidays	½ per cent
Extra Labor on Sundays and Holidays	½ per cent
Total	13½ per cent
Add Administration and Overhead Charges	1½ per cent
Grand Total upon the Cost of the Fire Protection System	15 per cent

This would upon the cost of the fire equipment amount to approximately $4170. If now the mutual insurance rate upon this property be added amounting to approximately 7 cents per $100 of risk, or $910 per year, the total cost of fire protection service and insurance, excluding the payment to be made to the water works for the water service, would amount to $5080. Without the sprinkler service the rate upon such property in the stock insurance companies might be $1 per $100 of risk, in which case the saving effected would amount to approximately $8000 per year. If the rate given by the stock companies were less than $1 per $100 of risk, the saving would be correspondingly reduced. It is probably safe to say, however, that the equipment would be paid for by the saving in insurance in a period of not over 5 to 6 years, if nominal charge only be made by the water works for the service rendered by it to the mill.

TYPE OF CONSTRUCTION	*A* MILL	*B* MILL	*C* MILL	*D* MILL	*E* JOISTED BRICK	*F* FIREPROOF
Occupancy	Leather Storage	Mfg. of Air Products	Metal Workers	Metal Workers	Storage Warehouse (Merchandise)	Loft
Total Floor Area	144,000	25,000	72,000	48,000	23,800	42,800
Cost of Sprinkler Installation	$13,000	$2,550	$13,400	$6,000		$6,600
Cost of Water Supplies	1,650	2,450	4,600	2,000		2,500
Total Cost	$14,650	$5,000	$18,000	$8,000	$4,700	$9,100
Yearly Charges						
Interest and Depreciation at 7½ per cent	$1,060	$360	$1,300	$580	$340	$660
Maintenance	600 *	600 *	900 *	900 *	150	200
Total	$1,660	$960	$2,200	$1,480	$490	$860
Insurance carried, Bldg. and Contents	$460,000	$285,000	$500,000	$200,000	$80,000 *B* $1,000,000 *C*	$200,000 *B* $250,000 *C*
Rate in Dollars and Cents per 100 Dollars per Year						
Before Installing Sprinklers in Building	$0.71	$0.53	$0.71	$0.75	$0.17 B 0 20 *C*	$0.20 B 0.55 *C*
After Installing Sprinklers in Building	$0.17	$0.09	$0.12	$0.07	$0.11 *B* 0.8 *C*	$0.084 *B* 0.22 *C*
Total Insurance Premiums						
Before	$3,260	$1,510	$3,550	$1,500	$136 *B* $2,000 *C*	$400 $1,375
After	780	256	600	140	88 *B* 800*C*	168 550
Saving						
Amount	$2,480	$1,254	$2,950	$1,360	$1,248	$1,057
In Per cent of Cost of Equipment	17	25	16	17	27	12
Cost of Alternate Water Supply (1500 gallon pump installed in separate pump house, also suction reservoir)	$3,500	$3,500	$3,500	$3,500	No city water	No city water

* Maintenance includes cost of night watchman; this service is taken in consideration in fixing final rate. *Average yearly cost of maintenance,* excluding watchman, *is from 2 to 4 per cent of cost of system.*

There can be no doubt that the saving resulting from the installation of private fire protection service is generally substantial, and this saving applies as well to the community as to the individual, for while the loss to the individual or corporation, of property destroyed by fire, and the loss to neighboring properties resulting from it, may be serious and irreparable to the individuals or corporations effected, the losses resulting from interruption of the business carried on within the property burned and the serious economic changes and consequent damages or loss incurred by or due to fire, particularly in the case of small communities having but few industries, may be much more far reaching.

Private fire protection is therefore desired not alone to prevent the risk of serious fire, limit the spread of fire and to decrease the actual loss in case of fire, and with it the cost of insurance, but also to reduce the losses and consequential damages resulting from interruption of business.

Propriety of Charge for Private Fire Protection Service

The two points of view with regard to the propriety of making charge for private fire protection service may be briefly summarized thus:

First, The water works are compensated for fire protection service by direct payment from taxation, or by the annual hydrant rental payments. Why then should the installation of special devices, such as private hydrants and sprinkler service, which involve substantial cost to the insured, both in construction and maintenance, which decrease the liability of fire, the spread of fire, and the loss by fire, and which if they do not effect a saving in the cost of operating, at least do not increase the financial burden of the water works, lead to the levying of an additional tax upon the progressive citizen, who while protecting his own property, indirectly reduces in large measure the hazard of his neighbors and of the general public? Instead of discouraging the installation of private fire protection devices, should we not rather encourage their use? Would it not be more logical to tax the unprotected risks, which by reason of their selfish and often misguided policy of refusing to install private fire protection service, become a real menace to their protected neighbors? For they in effect make the community bear the burden of their individual risk of loss of property, and the consequential losses arising from interruption of their business.

Second, From the other point of view, while admitting the desirability of inducing owners to equip their industrial or commercial risks with private fire protection service, in the interest of their neighbors and the public as well as of themselves, it may be held that special service of a higher order than that involved by the public fire protection service, and involving somewhat higher cost to the water works, and greater hazard to the integrity of the public fire supply, is involved in the furnishing of private fire protection service, and it is further contended that in the final analysis this is, in part at least, a question of policy in the distribution of the cost of maintaining the water works. While the community does benefit indirectly by the installation of private fire protection service, the chief direct gain is to the insured, in reduced insurance premiums and in the reduction of, if not freedom from, interruption of his business. The insured actually receives an annual dividend upon his investment in his private fire protection service and hence it is contended that a reasonable portion of this direct saving should go to the water works, which by coöperating with him make possible this saving, particularly, as the installation of these devices does involve some increase in hazard of loss of effective pressure in the general pipe system on account of discharging sprinklers and on account of services, risers, or hydrants broken, during fires.

BASIS OF CHARGE FOR PRIVATE FIRE PROTECTION SERVICE

Is not the question of practical expediency, an important factor in this problem? If the payment made for public fire protection service is commensurate with its cost is it not better policy, and upon the whole more equitable, to make a nominal charge only for the private fire protection service and to encourage in largest possible measure the installation of fire protection equipment, to the general advantage of the community, than to increase the cost of the private fire protection service to the protected risk, to a point commensurate with its *value* to the insured?

In the majority of cases the reservoir, pumping station and pipe capacity required to serve the private fire protection services, in excess of that demanded by public fire protection service, is small if not negligible.

On the other hand in those cases in which actual increase in capacity is required, the additional cost of this service should in equity be charged to the private fire protection service.

In those cases in which the payment for the public fire protection service is inadequate and incommensurate with its cost, a different condition exists. Here it may be asked, should not the cost of the private fire protection service be borne by it, and not by the commercial and domestic consumers? The writer inclines to the view, however, that even under these circumstances, it is preferable to put the burden upon the domestic consumer in large measure as he may right the evil by his ballot and place the burden where it should justly lie. To attempt to place any considerable portion of this burden upon the commercial service, would in many cases drive the commercial service into developing private water supply, at least in those cases in which the resulting charge might amount to more than the cost at which independent service could be had.

If the charge for private fire protection service is based upon the bare cost of the particular service rendered over and above the cost of the general public fire protection service, it should cover:

First, The cost of cutting into the street main and making the necessary connection from this main to the property line. The insertion of additional gates at the ends of the block upon which the service is located, if such gates are not already in place there. The insertion of a gate advantageously located upon the service. The installation upon the service either of a gated bypass with small meter upon it, or of a detector meter or other device for detecting or recording flow.

Second, The cost of a system of double check valves, with petcocks between them to test their tightness, if another source of supply which may be polluted is connected with the service and if such a system of check valves may be counted upon under existing conditions to safely protect the public supply. If not, the two sources used should be upon independent service pipe lines.

Third, The cost of water used or lost by leakage upon the service.

Fourth, The cost of maintenance, depreciation and interest upon the service, if it is not paid for by the insured when installed.

Fifth, The cost of maintenance, depreciation and interest upon that portion of the water works plant which is necessitated, or required, *solely* for the service of the private fire protection connections and which is *in excess of* the capacity required for the domestic, commercial and public service, including in the latter the public fire protection service.

Sixth, The cost of periodic inspection, reading of meters, testing devices, etc.

Seventh, The cost of maintaining inspectors in large cities, whose duty it shall be, to be thoroughly informed as to the location of all private fire protection services, to inspect them frequently and to attend all fires. In the case of smaller works, this work would be done at intervals by the regular operating force, and under such circumstances its cost should equitably be charged to the private fire protection service.

These charges, excepting the third item, which covers the cost of the water used, should be made independently of, and in addition to the charge for the water actually used. In aggregate amount, they will be small, generally substantially less than the actual saving, to the protected risk in insurance premiums, over the cost of the private fire protection service.

It is recognized, however, that under different conditions, which are the outgrowth of years of practice and local circumstances, different methods may equitably apply. Thus Mr. Miller of the engineer corps of the Railroad Commission of Wisconsin has told you today, that he is clearly of the opinion, as a result of a thorough study of the Milwaukee conditions, that no charge should be levied there for the ordinary private fire protection service.

METHOD OF LEVYING CHARGE FOR PRIVATE FIRE PROTECTION SERVICE

Various methods have been used in levying charges for private fire protection service:

First, Annual charge for service connections of different sizes.
Second, Annual charge for private hydrant service or connection.
Third, Annual charge for each sprinkler head.
Fourth, Annual charge for service based upon floor area.

Of these the first, an annual rental or charge for all services of given diameter seems upon the whole the simplest and most satisfactory of application, giving to the insured the advantage resulting from putting in as complete a system of private fire protection service as practicable, to protect himself and indirectly protecting his neighbors and the community.

GENERAL RULES GOVERNING THE SIZE AND ARRANGEMENT OF SERVICE CONNECTIONS FROM PUBLIC WATER SUPPLIES TO PRIVATE FIRE PROTECTION SYSTEMS

The rules suggested by the National Fire Protection Association, which were mainly the work of Mr. E. V. French, whom many of you must know as a very fairminded man, as well as an able fire protection engineer, seem to the writer admirable in their way and worthy of the support of this Association, if the insurance companies will but leave their interpretation to a bureau or board or committee of engineers, skilled in fire protection work and equipment and recognized as of judicial temperament, rather than to their local insurance agents. This does not mean that the final adjudication of cases in dispute should be left to these especially equipped insurance engineers in the employ of the insurance companies, but merely that the insurance companies should leave to these engineers, rather than to their local agents the interpretation of these rules. It is also suggested that somewhat greater emphasis than that indicated in these rules, should be laid upon the desirability of not exceeding a maximum diameter of 4 inches for the fire protection service pipes, except under unusual circumstances or upon well isolated risks, when the hazard involved by the change will be but slight.

RULES FOR SIZE AND ARRANGEMENT OF SERVICE CONNECTIONS FROM PUBLIC WATER SUPPLIES TO PRIVATE FIRE SYSTEMS, SUGGESTED BY THE NATIONAL FIRE PROTECTION ASSOCIATION

Isolated Risk

1. Permit 4, 6 and 8-inch service connections into yards, and only in special cases larger ones where conditions warrant, and where more water is available and is needed for the best protection. (Here omit the 8-inch reference: Metcalf.)

2. Every service connection into the property to have an outside gatevalve located where it will be accessible in case of a fire in the property. The local conditions should be studied in each case and the arrangement best fitting the special surroundings adopted.

3. Every connection over 2 inches in diameter from the yard mains into buildings to have an outside valve located where it would be accessible in case of a fire in the building. This applies mainly to connections for sprinklers or hose standpipes, but also would apply to any connection over 2 inches for manufacturing or other purposes. Valves on such connections cannot always be located as safely as those on the main service connections required by Section 2 but should as far as possible be located with the same ideas of accessibility.

4. All such controlling valves larger than $2\frac{1}{2}$ inches to have indicator posts, or where posts are not feasible, to preferably be located in valve wells, the gates to be of the outside screw and yoke pattern, and the location of all such valves to be plainly marked by signs which will be always visible.

Congested City Risks

1. Four-inch service connections to be used for smaller equipment, where this size of pipe will furnish ample water for the equipment and the connection enters directly into the building.

2. Six-inch connections to be permitted where the size of the equipment requires more water than a 4-inch connection can deliver. Where the sprinkler systems can be designed in two or more sections and the arrangement of buildings permits taking connections from different street mains, or from well separated points on the same main, it is better to provide two or more 4-inch connections, each supplying separate and independent sections of the system, where this can be done without unduly increasing the cost or decreasing the efficiency of the sprinkler system. This reduces the chance of one break causing a serious waste of public water, or an interruption of service to more than one section at a time. Where pressure is high and mains large, 4-inch services will often supply ample water; where pressure is low or mains small, larger services are necessary to bring enough water to give efficient sprinkler protection. Where in city risks the controlling valves required by Article 3 are favorably located so that they would be accessible and likely to be properly handled in case of fire, 6-inch connections could more freely be permitted.

(The added cost of two 4-inch connections or one 6-inch connection, is not to be urged as a cause for such substitution; Metcalf.)

3. All such service connections to have outside controlling valves in one of the following ways:

a. At the curb line with an indicator post.

b. At the building line with an indicator post set in a recess in the building wall.

c. In a valve pit near the middle of the street, or at the curb if a cover in the street is liable to be obstructed by snow or ice.

d. In some cases the connection may be looped back and the indicator post or valve pit set on the opposite curb across the street from the building protected; or the connection may, in some instances, be offset so as to come opposite an adjacent building rather than the one supplied.

e. Frequently the controlling valve can be placed opposite a stair tower or a division wall, where there is the least chance of falling walls making it inaccessible.

f. Valves of the outside screw and yoke type should preferably be used where indicator posts are not practicable. Street mains should be so gated that in case of necessity not more than a block length, or a maximum of 500 feet of main, will be shut off.

4. All valves on fire services to be plainly marked with the direction to turn to open, size of service and what it controls. This marking can go on indicator posts where they are provided. Where the valves are in the ground plain signs should be put on adjacent building walls, giving also the distance in feet to the valve. It is probable that some uniform sign in wording and color can be developed for any one city which would be recognized wherever seen. It may further

be possible to have a standard adopted for use in all places, thus giving the quickest recognition to such valves.

5. All manufacturing connections above 2 inches to be similarly provided with gates.

6. In cities having a number of buildings protected by sprinklers a small squad of intelligent men should be organized to handle the valves in case of fire under the direction of the chief of the fire department. This squad could be formed either from the fire or water department, or possibly from both. With the growth of automatic sprinkler equipments it is necessary to have an efficient body of men who will understand the value of sprinklers and the best method of handling them to take charge of these matters at severe fires. The fullest use of private protection requires in cities that valves be cared for by men who especially understand the whole system and who will work in full conjunction with the public department.

ACTUAL PRACTICE IN THE UNITED STATES IN REGARD TO THE INSTALLATION OF PRIVATE FIRE PROTECTION SERVICES AND CHARGES MADE FOR WATER SERVICE THROUGH THEM

In response to 2500 circular letters sent out by the secretary of the American Water Works Association, asking for information in answer to certain questions relating to private fire protection service, there were received approximately 370 replies, covering current practice in 364 towns and cities.

The task of collating, sifting and analyzing the data, contained in these circulars, has been a most difficult one, for in many cases the replies were not complete, and in others the questions were evidently misunderstood.

In general it may be said that at the present time there does not appear to be any well-defined standard for service or for payment for private fire protection connection with the water works in the cities of this country.

In addition to preparing a general tabulation of the data contained in the replies received, effort has been made to analyze independently the answers given to each of the questions submitted. This analysis follows:

Question 1. Maximum diameter of tap and service allowed for private fire services?

Of 314 replies 79 per cent have and 21 per cent have no maximum.
Of the number reporting maximum limits:

49 per cent report	6-inch diameter maximum,
24 per cent report	8-inch diameter maximum,
18 per cent report	4-inch diameter maximum,
6 per cent report	less than 4-inch diameter maximum,
2 per cent report	12-inch diameter maximum,
1 per cent report	10-inch diameter maximum.

Question 2. Is size of service limited by size of main tappe?

The character of the replies varied so and was so indefinite as to make it difficult to determine their real significance. Broadly speaking it may be said, however, that the replies were about equally divided upon the line of the existence or nonexistence of such a limitation.

Question 3. If based on size of main, what per cent or portion of the capacity of the main is allowed?

One hundred and forty-nine replies were received, some of which indicated that the writers did not clearly understand the intent of the question. Approximately one-third of the works reporting permit connections to the main of like diameter, in fire protection connections of small diameter. About one-third limit the size of the connection to a diameter smaller than that of the main, and about one-tenth limit it substantially, as for instance to one-fourth of the carrying capacity of the main, and the remainder have no set standard.

The replies to this question indicate in general that there is no marked tendency to limit the diameter of the fire protection service pipes in any substantial degree when taking water from pipes of diameters up to 6 or 8 inches.

Question 4. Do you require indicator post valves on private fire services?

Of the 307 replies received:

66 per cent answer "no",
30 per cent answer "yes",
4 per cent report no regulation.

Question 5. If indicator post valve is used what distance from building do you require it to be set?

92 replies were received. 28 per cent report specific distance, 25 per cent "at or near" curb, 11 per cent determination by insurance company, 12 per cent at street or property line, 24 per cent vague or different standards.

The 26 replies (28 per cent having standards for the distances, specify the following distances:

5.....5 to 10 feet distance
1..... 15 feet distance
2..... 20 feet distance
1..... 22 feet distance
5..... 25 feet distance
3..... 30 feet distance
2..... 40 feet distance
6..... 50 feet distance
1.....100 feet distance

Question 6. When indicator post valve is used, do you also require valve at main with street valve box?

Of the 225 reporting approximately 93 per cent do, and 7 per cent do not or have varying standards.

Question 7. Do you meter private fire services?

Of the 318 reporting, 26 per cent do; 12 per cent do partially; *62 per cent do not.*

Question 8. If not metered how are private fire services controlled?

163 replies specify:

36 per cent by sealing valves and openings,
34 per cent by inspection,
6 per cent by bond, fine, and contract cancelling,
5 per cent by some form of bypass,
5 per cent by separate lines,
11 per cent no control,
3 per cent not classified.

Question 9. If metered, how?

Out of 82 replies, 65 per cent use detector meters, 23 various types of meters, and 12 per cent could not be classified.

Question 10. Do you charge for private fire protection service?

Of the 331 replies:

48 per cent make a charge of some kind,
51 per cent make no charge,
1 per cent is unclassified.

Those works making a charge for the installation only, but no annual charge for service, were classified under those making no charge.

Question 11. If charged, how is charge based?

Classification of the replies received to this question is impossible and the number of complete replies is so small as not to justify the drawing of any definite conclusions. It may be said, however, that the replies indicate that upon hydrants located both inside and outside of the building an annual charge per hydrant is made, upon sprinklers a charge per sprinkler head and connection, per unit area of floor space, per size of building, fire risk, value of property, and charge for auxiliary connection, or "ready to serve" charge.

Of the replies received to this question 5 base their charge upon valuation of property; 14 upon flat rate including all fixtures; and the remainder may be subdivided as follows:

	INSIDE HYDRANT	OUTSIDE HYDRANT	SPRINKLERS	STAND READY OR AUXILIARY CONNECTION
	a	*b*	*c*	*d*
Size of connection or size of meter	26	26	29	37
Per connection	[illegible]	4	13 (1)	9 (2)
Metered rates	11	9 (1)	8 (1)	11(2)
Area covered or area of floor space	5	0	10	[illegible]
Yearly rental	(35 (2)	63) (1)		
Yearly rental same as city's	(8 (1)	15) (1)		
Size of building, fire risk, etc.			[illegible]	
Per head			36 (10)	
Per floor	1	1		

(Shows number having a minimum charge.)

Question 12. What is amount of charge?

The answers received to this question vary so as to make satisfactory classification impossible. The following tabulations indicate, however, the general limits covered by the charges reported.

Charges Based upon Size of Meter

INCHES									
¾	1	1½	2	2½	3	4	6	8	10
$18[2]	$24	$30	$24	—	$16	$32	$64	2–$120	$144
			36	—	36	48	72	128	
			2–60[2] [3]	—	48	60	84		
					96	100[2]	240[2]		
					120[2]	144	504–300[5]		
						240[2]			

[2] Minimum. [3] Maximum. [4] They Furnish. [5] We Furnish.

Charges Based upon Size of Connection or Tap

INCHES								
¾	1	1½	2	2½	3	4	6	8
$1	$2	$3	$5	$5	$5	$7.50	$10	$32
3	3	4	2–10	20	7.50	0	24	36
			12					
	5	10	15	25	12	12	25	60
		15	16		15	24	30	64
		25	2–20		18	30[7]	48	100
			24		24	32	60[7]	150
			25		30	40	2–75	3–400
			30		35	48	2–100	
			35		36	50	2–200	
			2–50[6]		50	80	240	
					25	2–100		
						160		

[6] Minimum. [7] Maximum.

Charges Based upon Flat Rate for Each Private Fire Service

4 at $18, $20, $24, $25 per year
3 at $50 per year
1 at $10 to $75 per year (depending on size of main)
1 at $24 to $300 per year (no hydrants, etc.)
2 at $100 per year
1 at $125 per year

Charges Based upon Valuation

1 at 37½¢ on $1,000 valuation with discount varying with amount of water used, 1 at $25 for $50,000 valuation or less, $50 for $50,000 to $100,000; $75 for $100,000 to $200,000; and $100 for over $200,000 (per year).

a. On private hydrants inside?

Of the 46 replies which could be classified:
24 per cent from $20 to $30 annually per hydrant,
20 per cent $10 or less,
17 per cent $40 to $50,
16 per cent $10 to $20,
11 per cent $30 to $40,
6 per cent $1 per 1000 sq. ft. served,
4 per cent $3 per 1000 sq. ft. served,

2 per cent $1 per floor per hydrant with limit of 2 hydrants to a floor.
The number of replies received is too small to be of much significance.

b. On private hydrants?

Of the 76 replies received:

32 per cent $20 to $30 per hydrant,
28 per cent $30 to $40,
22 per cent $40 to $50,
17 per cent $20 or less,
1 per cent over $50.

c. On sprinkler connections:

INCHES							
1	1½	2	2½	3	4	6	8
$6	$12	$10	—	$15	$21	$43	$65
		18	—	36	2–25	3–50	100
		100	—	100	30	60	120
				300	35	72	
					48	120	
					150	300	
					200		
					500		
					75		

"Per Connection", no Size Given

1 at $20 per year,
3 at $25 and upwards (inc. 1 and double meter rates),
1 at $50
1 at $55
1 at $60
1 at $75 and upwards,
1 at $15 for 1st 2 standpipes; $10 for next 5; and $6 for all others,
1 at $20 for each 2" opening.

On Basis of "Number of Heads"

1 Single system at 1¢ and double system at 2¢ each per year,
9 at 5¢
1 at 5¢ to 6½¢
1 at 7½¢
2 at 10¢
1 at 12¢
7 at 5¢ with a minimum of $50 per year,
1 at 9¢ with a minimum of $50 per year,
1 at 10¢ with a minimum of $20 per year for 100 heads or less.
1 at 10¢ (4") with a minimum of $100 per year for 1000 heads or less,
1 at 10¢ (6") with a minimum of $150 per year for 1500 heads or less,
1 at $100 up to 750 heads, then additional heads at 6¢,
1 at $40 for 500 heads, then additional heads, at $8 per 100,
1 at $50 for 1000 heads, or less,
1 at 5¢ up to 300 heads, and 3¢ for heads over 300,
1 at 5¢ up to 3000 heads, and 1½¢ for heads over 5000,
1 at 20¢ for 1000 heads or less, over 1000 at 15c,
1 at 15¢ 1st 250; 10¢ for 2nd 250; over 500 at 7½¢,
1 at 10¢ 1st 1000; 7½¢ for 2nd 1,000; additional at 5¢,
1 at $25 1st 250; additional 500 at 5¢ over 1000 at 1¢,

On Basis of "Area of Floor"

4 at $1 per 1000 square feet,
1 at $3 per 1000 square feet,
1 at $75 minimum and 20¢ for each additional 1000 square feet,
1 at $10 per 10,000 square feet,
1 at $20 per 10,000 sq. ft. automatic, and $40 do. for non-automatic,
1 at $30 1st 10,000 sq. ft.; $20 2nd 10,000 sq. ft.; $10 each additional 10,000 sq. ft.,
1 at $10 1st 10,000 sq. ft.; 10,000–20,000 at $1 per 1000; 20,000 or more at 50¢ 1000,
1 at $50 for factory 200 ft. long and $100 for factories over 200 ft. in length.

d. On general "stand ready" fire connections:

1 at $10 for 1st; $5 for 2nd and $2.50 for others,
1 at $25 per 2½" opening,
3 at $50 minimum (1 at $5 for each 2" opening),
1 at $50 per connection,
1 at $25 to $50,
1 at $24 minimum,
1 at $100 to $300 on factories employing 500 men.

According to Size

INCHES							
1	1½	2	2½	3	4	6	8
		2–$25	$25	2–$35 37½	2–$10 2– 50	$15 25 60	$20 40

Question 13. Are private fire protection charges in addition to regular rates or are they remitted if the other charges for water exceed the maximum charges for fire protection.

Of the 76 replies received, 82 per cent report the charges to be additional, and 18 per cent in offset to the charge for water, that is "remitted."

The replies received to the circular have been bound and filed in the writer's library, where they are subject to reference by members of this Association.

SUMMARY OF CONCLUSIONS

1. There is no standard practice today among water works in the United States with reference to the character of or charges for private fire protection service.

2. The "Rules of the National Fire Protection Association" relating to size and arrangement of service connections from public water supplies to private fire protection systems as applied to isolated and to congested city risks quoted herein (page 141) appear conservative and worthy of trial if the insurance companies will only leave their interpretation, for them, to an independent board or committee of competent and judicially minded fire protection engineers, rather than to their local insurance agents, and will agree to a conservative interpretation of the right to use larger service connections than a 4-inch maximum contained in their rules.

3. While in the majority of cases 4 inches is a desirable maximum limit for the diameter of private fire service connections or pipes, particularly in the congested or thickly built up sections of the community, and while it is desirable that greater capacity should be gained by adding other 4-inch service pipe connections or units rather than by increasing the diameter of the connection, it is recognized that in some cases, more particularly in large and well isolated risks, service pipes of larger diameter can safely be approved.

4. The private fire protection service should be absolutely independent of the industrial, commercial or domestic service and be limited to use for fire fighting purposes.

5. The private fire protection service should be equipped with connection for pitometer readings, with valve and metered bypass, or with detector meter of some kind, for inspection and detection, or metering of consumption, resulting from leakage, waste or use of water, as local and financial considerations shall show to be expedient or necessary.

6. Past experience in different communities indicates clearly that abuse of privilege may be successfully controlled by the following methods, which may advantageously be applied successively, if the minimum cost of furnishing private fire protection service is desired:

a. Use of seals upon hydrants, blowoffs and other gated connections, coupled with periodic inspection by water department and agents of the insurance companies,

b. Periodic inspection coupled with use of pitometer or metered bypass upon service,

c. Use of detector meters, particularly in installations where the added cost of the meter will not be burdensome.

7. The question as to whether or not charge should be made for private fire protection service depends largely upon local conditions and circumstances. There is good ground in equity for urging upon the one hand that no charge should be made for such service, in addition to the charge for public fire protection service, and upon the other hand, that a moderate charge based upon the cost of the special service rendered, together with the additional cost of inspecting private fire protection services, would not be inequitable or burdensome.

In such cases as the payments for public fire protection service are commensurate with its cost, and probably in many other cases as a matter of expediency in encouraging the installation of private

fire protection connections and devices for the better protection of the community against hazard of fire, it is believed to be desirable that a nominal charge only should be rendered for private fire protection service.

8. If a nominal charge only is made for private fire protection service, it should cover:

First, The cost of cutting into the street main and making the necessary connection from it to the property line. The insertion of additional gates at the ends of the street block upon which the service is located, if such gates are not already in place. The insertion of a gate advantageously located upon the service. The installation upon the service either of a gated bypass with small meter upon it, or of a detector meter or other device for detecting or recording flow.

Second, The cost of a system of double check valves with petcocks between them to test their tightness, if another source of supply which may be polluted is connected with the service, and if such a system of check valves may be counted upon under existing conditions to safely protect the public supply. If not, the two sources used should be upon independent service pipe lines.

Third, The cost of water used or lost by leakage upon the service.

Fourth, The cost of maintenance, depreciation and interest upon the service if the latter is not paid for by the insured when installed.

Fifth, The cost of maintenance, depreciation and interest upon such portion of the water works plant as may have been necessitated by the demands of the private fire protection service alone, and which is in excess of the capacity required for the domestic, commercial and public service, including in the latter public fire protection service.

Sixth, The cost of periodic inspection, reading of meters, testing devices, etc.

Seventh, The cost of maintaining inspectors in large cities, whose duty it shall be to be thoroughly informed as to the location of all private fire inspection services, to inspect them frequently and to attend all fires. In the case of smaller works, this work would naturally be done at intervals by the regular operating force. Under such circumstances its cost should equitably be charged to the private fire protection service. These charges excepting the third item, which covers the cost of the water used, should be made independently of, and in addition to the charge for the water actually used.

9. The distribution of the charge levied for private fire protection service can perhaps most simply, directly and equitably be levied as an annual service charge for each service pipe connection, increasing the amount of the charge with the pipe diameter.

In conclusion the writer desires to express his obligations to Mr. George W. Booth, Chief Engineer of the National Board of Fire Underwriters, Mr. L. H. Kunhardt, Vice President of the Boston Manufacturers' Mutual Fire Insurance Company, Mr. E. V. French, Vice President of the Arkwright Mutual Fire Insurance Company, and to various other engineers, water works superin-

tendents and insurance company representatives for information kindly furnished, and regrets only that it was impossible for him to prepare and present this paper in collaboration with Mr. Emil Kuichling and Mr. William C. Hawley on account of lack of time and opportunity to discuss jointly with them the questions involved.

HOW A PUBLIC WATER SUPPLY WAS POLLUTED BY A PRIVATE FIRE SERVICE—AND THE CONSEQUENCES

By R. J. Thomas

Of late years, it has become the policy of Fire Insurance Organizations and Underwriter Bureaus throughout the country to require industrial risks to have two systems of fire service, a primary service, usually from the public water works supply, and a secondary service from a private source, with pumps, tanks, etc. This double requirement was to provide against loss of fire protection in case either of the systems should prove inoperative for some reason or other.

In the eastern part of the country, particularly in manufacturing centers, where the Factory Mutuals did the bulk of the underwriting business, the two systems of fire service have been in practice for over twenty-five years. In some cases the usual conditions of supply were reversed, and, instead of the public water works system being the primary service, it became simply an auxiliary or secondary supply, but both were so connected that they were really one as far as the water supplied was concerned. True, they were separated by check valves which, for many years, were supposed to prevent a mixing of the waters, and no trouble was apprehended from this arrangement.

This was the case in Lowell, Massachusetts, in July, 1903, when the occurrence took place which forms the subject of this paper, and which resulted in a total loss of confidence in the check valve as a defense against impure water in a private system of fire pipes flowing into a public water supply.

For years antedating the construction of the Lowell Water Works, the Locks and Canals Company of that city had a system of water works built for the protection of the mills and other property of the 9 large manufacturing establishments which formed the Locks and Canals Company. Later, when the City Water Works was constructed, this company succeeded in getting the city to lay

a 20-inch main known as the corporation line, and connect this line at 13 different points with Locks and Canals' main by means of 12-inch pipes equipped with gates on each end of connecting pipes.

At first, the 12-inch gates on the city side were to be kept shut, and opened only in case of fire in the mills. In course of time, however, check valves were set by the Locks and Canals Company on the connecting pipe opening towards their system, with the idea that their reservoir being 35 feet higher than the city reservoir, the extra pressure of 15 pounds would operate to keep the check valve closed and hold the city water back, excepting when their reservoir (in the event of a big fire, etc.) was drawn down to a point below the city pressure, then the check valve would open and the city water would flow into their pipes and supplement their service, but in no case, so it was thought, was there a chance for the Locks and Canals' water to get back into the city mains.

As to what actually happened in this case, the writer will quote from the report of the Lowell Water Board for the year 1903.

> On Saturday, July 18, there occurred a fire on the Merrimack Corporation, at which the Locks and Canals' reservoir was drawn upon to such an extent that the pressure in their pipes went below the city pressure. Consequently, the check valves between the two systems opened, and the city water flowed into the Locks and Canals' pipes until the fire was extinguished. Some time after the Locks and Canals Company started pumping, it was found that their reservoir did not fill, and on investigation, it was found that a check valve situated on the Massachusetts Corporation near the corner of Canal and Bridge Streets had failed to close, and water from the Locks and Canals was flowing into the city mains. Within a few days an epidemic of sickness appeared resembling cholera morbus, and later developed many cases of typhoid fever.

The fire was declared all out at 11 o'clock P.M., no water being put on the fire after that time. For some time previous, however, the pump which supplied water to the Locks and Canals' system had been put into operation and was rapidly filling their pipes, but the normal pressure was not in evidence, and until 9 o'clock A.M. the following morning, Sunday, they were sorely puzzled to figure out what the trouble was.

At that time, by shutting off the connection between the two systems at the corner of Bridge and Canal Streets, their pressure went up and the problem was solved—the check valve didn't check, and part, if not all, of the water they pumped passed into the city mains. They didn't think enough of the matter to notify the water department until the following Monday morning, when one of their officials informed the superintendent casually that they returned

the water consumed on the fire. When explanation was demanded, the foregoing facts were related.

Further investigation on behalf of the city discovered the additional fact that the water pumped was from the wheelpit of one of the mills, and, it being Saturday night and Sunday, the mills were not running and about all the water in the wheelpit flowed in from a trunk sewer that discharged into the river near the wheelpit, about 600 feet distant.

Figures based on the ordinary daily consumption, 5,500,000 gallons, and the quantity pumped at the time showed about 500,000 gallons of water in excess of normal, which was probably the quantity entering the city pipes from the Locks and Canals' pipes through the defective check valve.

No wonder considerable sickness followed. One hundred sixty-eight cases of typhoid fever and 9 deaths were reported during the following months of August and September, against 15 cases and 6 deaths in 1902, and 13 cases and 1 death in 1901. The cases were reported weekly as follows:

	Cases	Deaths
August 8 to 15	13	0
August 15 to 22	75	1
August 22 to 29	41	1
August 29 to September 5	20	2
September 5 to 12	7	2
September 12 to 19	8	2
September 19 to 26	4	0
September 26 to October 3	4	1

The time during which this socalled water flowed into the city mains was from 11 o'clock P.M. Saturday to 9 o'clock A.M. Sunday when the gate leading to check valve was closed by an employe of the Locks and Canals.

A significant fact connected with this affair was that the check valve in question had been undergoing repairs the week of the fire, and the stop gate on the city side which had to be closed for the purpose and was supposed to be kept closed until opened by the water department, was not so opened, but was opened by a Locks and Canals' employe during the fire, according to testimony given in court, notwithstanding that such opening was contrary to law and was without the consent or knowledge of the water department. The same employe closed it Sunday morning at 9 o'clock, thereby stopping further pollution of the city water.

Where the Locks and Canals' water was supposed to enter the city pipes on Canal Street, the general flow of the water was in a northwesterly direction through the business center of the city to the Highlands, a residential section, where most of the sickness occurred. In the business section, it being Sunday morning, very little of the mixed water was used, that is to say, judging by the consumption, the velocity of the water must have carried it beyond that section in a few hours after entering the 20-inch main, so that on Sunday about noon the people of the Highlands probably received a pretty raw dose of it.

As nearly as could be estimated, about 3,000,000 gallons of the 5,500,000 gallons used every twenty-four hours, passed though this 20-inch main receiving the polluted water, and at the rate of consumption as above, very little, if any, of the polluted water was left in the pipe system at the end of twenty-four hours.

As soon as possible, after receiving information of this pollution of the city's water mains, they were thoroughly blown off so that if any contamination remained, it would be gotten rid of in this way. The State Board of Health took samples of the water in different parts of the city, finding a trace of bacillus coli in only two samples of 100 c.c. and in the series of samples tested, the average number of bacteria was about 10 per c.c., so that the typhoid epidemic was undoubtedly due to the water drunk on Sunday and before the department knew of it, and of course before any action could have been taken to warn the public of the danger.

One suit was brought against the city for illness, but it was understood that the attorney bringing the suit had 40 other cases ready, awaiting the success of the first, or "Cowley" case, as it was called. The "Cowley" case dragged along for several years, finally to be disposed of with a verdict for the city.

Mr. Cowley, the plaintiff, died before the case was finished, but his relatives kept up the fight. Mr. Cowley's claim was that an attack of gall stones, from which he suffered the February following the injection of the polluted water, was caused by a drink of water which he took about noon on Sunday. Expert medical testimony was introduced to prove that gall stones cou'd be brought about by polluted water. Many and various were the points of contention that appeared during the trial, but the great point of all for the plaintiff to establish, as to whether the water from the Locks and Canals' pipes actually entered the city mains, failed of proof according to the judgment of the auditor who heard the case. Be it

understood, however, that the facts herein related were not fully brought out at the hearing.

Another consequence was the absolute and complete separation of the City Water Works pipes from any and all other sources of supply. For this purpose the following regulations were adopted in 1903 and strictly enforced ever since:

PREAMBLE. No fire service pipe shall be laid into the premises of any corporation, firm or individual having connected therewith, directly or indirectly, supplementary or secondary fire service consisting of fire pump, cistern, tank, standpipe or other apparatus, excepting where such fire pumps, cistern, tank, standpipe, etc., are supplied with water from the City Water Works system and subject to the following regulations:

1. All water for fire service pipes shall be metered; meter to be furnished and set by city at the owner's expense. No charge shall be made, however, for water used exclusively for the extinguishing of fires.

2. All main pipes for fire services shall be furnished and connected by the city at the expense of the owner.

3. Where a standpipe, tank or cistern is used it shall be constructed in such a manner as to shield and protect the water from all possible pollution.

4. Provision shall be made in its construction for means of access to the interior of it by the superintendent or other agents of the water department for the purpose of inspection and so as to allow for its cleaning as required by the water department.

5. It shall also be fitted with a pipe for the purpose of drawing off all the water at such intervals as required by the water department.

6. Said drawoff pipe must not be connected with a sewer or drain in a way that might lead to the contamination of the water from such source.

7. All expenses not mentioned herein incurred on account of fire services shall be borne by the corporation, firm or individual owning the protected premises.

8. The water board shall have the power from time to time to prescribe whatever other rules they may deem necessary.

The check valve used was one specially made for the Locks and Canals Company and was substantial and well constructed. It had four flaps set in a diaphragm at an angle of about 45 degrees. The flaps were rubber faced, and stops were set on diaphragm so as to prevent flaps from staying open. It was probably as good as the best check valve made, but where the health and lives of the people are at stake, reliance should not be placed on any contrivance that operates either automatically or by hand. The safest plan is not to allow any connection, directly or indirectly, between the pipes of a public water works system and the pipes, tanks or pumps of a private fire service system containing a foreign water.

DISCUSSION

Mr. Henry P. Bohmann: We have about one hundred and fifty automatic sprinklers in Milwaukee, of which number only three are on metered service. While conditions are not of greater gravity in Milwaukee than in other cities having a similar number of automatic sprinklers yet the speaker believes that complete meterage is the only thing to protect the city and the water department. Up to a year ago there were no restrictions on automatic sprinkler systems further than a bond required in each instance. An inspection made, however, last year showed that this privilege has been greatly abused, notwithstanding the bond.

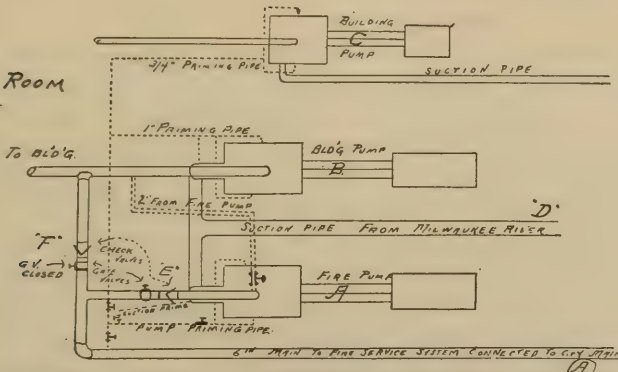
It may be interesting to hear some particulars as to one of these cases where the establishment was equipped with an automatic sprinkler system connected to the city mains, and having a fire service pump drawing water from the river. A 2-inch connection had been made from the pump discharge main, on the pump side of the check valve, to the discharge main of a smaller service pump, also drawing water from the river for the purpose of forcing this river water to various points in the premises. At the time of the investigation, the fire pump was found in operation, forcing, it was claimed, river water throughout the entire fire protection system and through 2-inch cross connecting pipe from the pump to the building service line for the purpose of assisting the building pump in the supply of river water. The gauge on the fire pump was held as evidence of this fact, inasmuch as the pressure indicated was fourteen pounds more than the city pressure.

The remarkable clearness of the river water discharged at various points, the "sweating" of the mains on the fire line, and the action of the fire pump aroused the suspicion as to the truth of this statement. The substitution of our own gauge for that of the pump gauge showed the pressure exactly "city pressure," and that the pump gauge had been tampered with. The fire pump was found in such poor condition as to the valves in the water chamber that the action of the fire pump was simply a bluff as far as service was concerned. The check valve on the discharge main had also been removed, thus permitting a full flow of the city water from the fire main through the fire pump into the cross connecting pipe to and through the building service line to the various points in the premises. A priming pipe one inch in diameter had been connected to

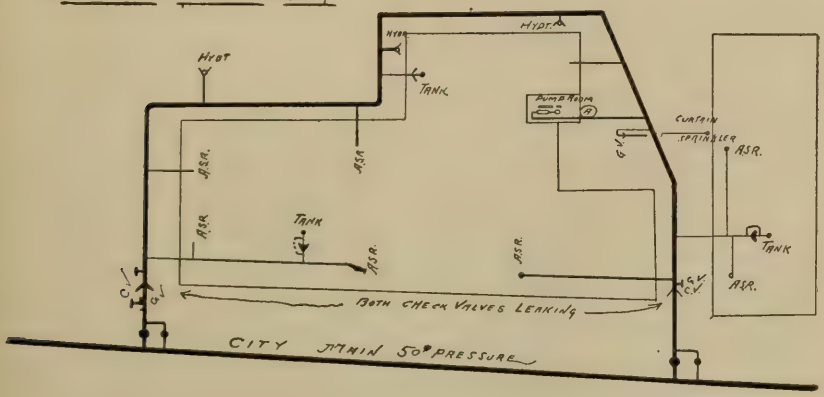
--- ILLEGAL FIRE CONNECTIONS
—— FIRE SERVICE

1" PIPE (FROM MAIN CONNECTED TO CITY MAIN) FOR PRIMING 3 PUMPS - AND SUCTION PIPE.
2" " (" DISCHARGE MAIN OF PUMP) TO DISCHARGE OF SMALLER PUMP THENCE THROUGHOUT BUILDING.
"A" FIRE PUMP VALVES IN WATER CHAMBER LOOSE - GAUGE INDICATING 14 POUNDS MORE THAN ACTUAL PRESSURE.
"B" BUILDING PUMP FORCING RIVER WATER TO VARIOUS POINTS IN BUILDING - 35 POUNDS PRESSURE.
"C" SMALL PUMP FOR PART OF BUILDING.
"D" SUCTION FROM RIVER - FOOT VALVE LEAKING - CITY WATER ON TO KEEP FILLED WHEN NOT USED.
"E" FIRE PUMP CHECK VALVE FLAP REMOVED. GATE VALVE ON THIS MAIN HELD OPEN BY OBSTRUCTION UNDER GATES WHEN SUPPOSED TO BE CLOSED
"F" GATE CHECK ON MAIN FROM "B" PUMP - USED AS AUXILLIARY FIRE SERVICE — IN CASE FIRE PUMP IS NOT IN SERVICE.

PUMP ROOM PIPING.



PLAN OF FIRE SERVICE SYSTEM



the building service pump and suction pipe, and water for priming purposes used from this main.

Drain valves on five automatic sprinkler risers were found leaking and the water wasting to the sewers at the rate of 20,000 gallons per day.

The frequent changing of automatic sprinkler heads, due to the corrosion thereof, in certain departments also caused an unnecessarily large wastage of water, inasmuch as these systems were drained each time for the replacing of these heads.

Orders were at once issued for the removal of all illegal connections, the repair of drain valves and the substitution of non-corrosive heads.

The total amount of water lost to the department through these connections and wastage on the system amount to 479,650 gallons per day. A reading of the building supply meter made one day after the discontinuance of this "free" water and one twenty-nine days later showed an increased consumption of 6,763,120 gallons and an additional 4-inch main put in service.

Now as to charging for fire services. The city of Milwaukee would make no charge for service of this kind provided the sprinkler services were metered, feeling that the additional revenue to be gotten through the registration of the fire service meter or the additional registration on the commercial meter would compensate the city for any expense that it is put to.

MR. DOW R. GWINN: You are putting meters on now?

MR. HENRY P. BOHMANN: On the 1st of January we had about 700 domestic services not metered. Under our charter it was optional with the consumer whether to put meters on domestic service or not. Inasmuch as we had 58,000 metered services it was very desirable to have the few hundred services that were not metered also metered. So we made a request to the Railroad Commission that they order the few hundred unmetered services to be placed on metered service. The speaker was aware that ordering the metering of the automatic sprinkler systems would precipitate a big fight from the Board of Underwriters as well as the business men, and so he wrote a letter asking the commission for further instructions, and received a reply stating that they were taking this matter under consideration and would make a study of this particular case. A perusal of the proceedings of the Winconsin

Railroad Commission will show that this has been a subject of debate for the last ten or fifteen years and apparently not a great deal of headway has been made. The speaker hopes, however, to hear from the commission favorably on the matter.

There are about fifteen factories equipped with fire service pumps drawing water from the river and connected with our city supply. In the past there were no inspections made of any kind at these plants. Recently our inspectors have investigated all of these plants, making pressure tests on both sides of the check valve. The Mutual Board of Underwriters recommended that a double check valve be put in; but the speaker is informed that even double checks are liable to get out of order. Because the department has other interests to guard it is desirable that these factories use this water for sprinkler purposes only, and to adopt some means that will make it impossible for them to use the water for other purposes. Where there is no meter it is an easy matter to draw on the city water for hose connections or other purposes. We finally decided to close and seal the discharge on the fire pump and in addition install one check valve, which check valve is under constant inspection. The only danger in case of fire will be that this particular valve might become out of order, but that danger is very remote, inasmuch as this check valve is under inspection all the time. So far the Board of Underwriters have worked hand in hand with us.

Mr. Walter E. Miller: The speaker understood Mr. Thomas to say that when the city water works was constructed the company succeeded in getting the city of Lowell "to lay a 20-inch main known as the corporation line, and connect this line at thirteen different points with Locks and Canals' main by means of 12-inch pipes equipped with gates on each end of connecting pipes." They were, apparently, using the river as a primary supply, and the city water as a secondary supply for these private fire pumps.

It does seem that there is a tendency to credit the city water service to such private plants with all the saving in insurance premiums; whereas it seems that only a small part of the saving is to be credited with the city water service where that is the secondary supply; so that it seems that there is considerable importance in ascertaining whether the city supply is the primary, or secondary source.

Mr. Metcalf's paper evidences an immense amount of work and very able thought in its preparation. The speaker wishes to

say, however, that he believes Mr. Metcalf has made one misstatement in saying that the Railroad Commission had passed on this matter in the Milwaukee case. The fact is that the Milwaukee case is still pending. The commission has not yet decided the matter. Such views as the speaker has expressed here are his own, and not as yet known to be those of the commission.

Mr. Metcalf referred to the policy in Europe of penalizing the owners of hazardous risks who have not provided automatic sprinkler protection. The speaker was under the impression that it was stated at the Louisville convention in the discussion of some of these questions, that in some foreign countries the owner of a building or plant in which fire originates and spreads to adjoining property is held responsible for the damage done to his neighbors' property; and the speaker believes that view is a sound one.

Mr. J. Walter Ackerman: The city of Auburn, N. Y., has had some experiences with check valves of the usual old style that were buried in the ground outside, and that would perhaps pass out of mind. On examination it was found that a number of these check valves leaked very badly, and the Board of Water Commissioners denied the right of connection to the water mains of any of the secondary services. As Auburn has large manufacturing interests, that, of course, came home pretty hard to the manufacturers, and together with the insurance interests, and a renowned Sanitary Engineer employed by the Water Board, a compromise was effected in this way: After some experiments certain sanitary check valves were finally O. K.'d by the sanitary expert, and were installed in tandem on every service, placed in an accessible pit so arranged that they could be easily tested at any time. They were tested for tightness twice a year, and once a year taken out and examined to see whether there was any trouble whatever with the valves.

In addition to that the discharge pipe on the fire pump is sealed and prohibited from being opened except in cases of fire. In case of the usual insurance test when notice is given to the department, some officer from the department goes and sees whether everything is all right. There are also installed on a number of these supplies detector meters on the fire lines, which furnish another check valve between the polluted supply and the city system. Where the yards are very large, trouble has been experienced, although it is not charged that the officers of the companies knew of

it, but the consumption was found to be three or four times the amount that the original meters recorded, and that of course was eliminated to a certain extent after opportunity had been given in such cases for the parties to find the leaks. In every case the consumption increased one hundred per cent. The President of our Water Board is here at this convention, and he has suggested that he would like to have the author of the paper on the Pollution of a Public Water Supply by Private Fire Service say what chances he thinks there are for pollution in the case of the installation in our city of Auburn.

Mr. Robert J. Thomas: The speaker would hesitate to take the responsibility of passing an opinion in the case cited, not being familiar with the local situation there, but generally speaking would feel more assured that he was doing his duty more conscientiously by refusing absolutely to allow any connection whatever with a polluted supply. Our inspectors are instructed to follow that up, yet they may at times become negligent, and in several cases the speaker has, when calling at factories for some other purpose, found the pipes containing city water connected with a private source of supply that was contaminated. Such a case occurred in a beautiful new building which the speaker visited recently for the purpose of putting in a fire service pipe, and happening to look at their system he found that they were connected with a canal, which supply was very much polluted. With not even a check valve on the pipe between the city water and the canal water, nothing but a hand operated valve, which in this case they claimed was always kept closed; but that was not reliable, because where so many men are handling a valve it is easy to forget about it and in that event considerable pollution might occur through a pipe two inches in diameter, sufficient to cause considerable typhoid or other illness where the connection is with an infected source.

Mr. W. H. Randall: With respect to the danger of pollution the speaker would cite one case in addition to those already named. In the city of Toronto a short time ago a very large corporation installed a pumping plant with connections to the Bay, to supply their boilers and other appliances throughout their plant, which was not to be connected with the domestic supply. One of their employees made a connection to a small service in the building that was connected with the domestic supply, and as a consequence

four or five cases of typhoid fever occurred within a short time. The medical health officer made some investigation after the matter had been referred to the Health Department, and as a result discovered this connection and located the source of trouble in the case. The Bay is nothing more or less than a cesspool, and these men had been drinking from a tap connected right to the Bay water.

Another case occurred just before the speaker came to this convention, which does not refer to pollution, but shows the danger of a check valve. The speaker was called up at night and told that the workmen could not succeed in shutting the water off from one street. They had closed one or two valves, but still the water was there. It was a case where the connections for fire protection for the same building had been taken, one from one street and one from the other, so that if one was shut off they could get a supply from the other. In this case it was discovered that the check valve was open and they were getting water from the other street. The men had to shut off the service on both streets before they could shut off the water.

Mr. W. E. Miller: Evidently there are a number of places where reliance is being placed on two check valves in series. Mr. Ackerman speaks of that practice having been followed in his case. The speaker would inquire of Mr. Ackerman whether the same annual tests of his check valves have ever disclosed that both were leaking?

Mr. J. Walter Ackerman: No, we have never discovered such a condition since the installation of what we call the sanitary check valves. It depends somewhat, of course, upon the way you conduct your test. If there is only a slight difference in pressure between the two sides there is occasionally a slight leak through one; but if there is as much as five or ten pounds difference on the two sides of the check valves we have never yet found a leak.

Mr. J. N. Chester: Mr. Miller's paper brought to the speaker's mind Ingersoll's dream of heaven and the conclusion he drew to wit, that the people that were in wanted out, and those that were out wanted in. Those outside of Wisconsin for a good many years have looked upon the actions and findings of the Wisconsin Public Service Commission as about ideal, and especially their attitude with respect to charges for fire protection; but here we find one in

who wants out, and who at least is protesting against dividing the charge for fire protection between public and private. Are we to understand that his opinion is that it should all go to the public and none to the private?

Mr. W. E. Miller: The conclusions stated by the speaker in his paper were with reference to the conditions existing in Milwaukee, and the closing paragraph of the paper stated that the author was not yet ready to admit that the principle was necessarily to be universally applied.

Mr. J. N. Chester: That fire protection is installed for the reduction of insurance is a well established fact; but to the statement that it does not cost the city or the company anything to provide the same after once installed, other than the inspection, the speaker cannot agree. That attitude has been insisted upon by a great many people, but the speaker, whether or not he may be charged with stubbornness, is of the same opinion still, and his conclusions in regard to this matter he still holds today, that a water works system is to any city or municipality a benefit, but at the same time also carries with it a burden; and the speaker believes with Hon. Halford Erickson that that burden should be proportionate as nearly as possible to the benefits derived. Now that may not agree with Mr. Metcalf's paper, or may not agree with Mr. Miller's conclusions; but the speaker's conclusions are that some portion of the burden should be assessable against the benefits of private fire protection. The question as to whether the supply is primary or secondary, and a great many other things, may enter in; but after all is said and done, if there is a connection to the water mains for private fire protection, there should be a charge made against the concern that has that connection, whether primary or secondary, in proportion to the benefits received and burden assumed, because of that connection being there.

As to the protection afforded by check valves, at Ashtabula, Ohio, where in certain cases a standpipe was required for fire protection, which standpipe was not needed for domestic supply, and consequently there was a check valve so arranged that when the pressure was raised by the pumps it would pass on into the standpipe. It becomes frequently necessary of course to replenish the standpipe, and, during four months, no less than fifty per cent of the time the pressure was raised enough to raise the check valve;

it refused to seat, necessitating its being jarred down into its seat. You will say that that was a bad condition of check valve, in which the speaker will agree with you. It probably needed overhauling. The hazard might be reduced by a duplication of valves; but on the other hand check valves are largely made ineffective by the corroding influence of water, and if there are two valves, while one is corroding, the other is probably doing likewise; can they be looked upon as the proper safeguard? On the other hand if they are not affected by corrosion, the duplicating of the check valve affords a greater measure of protection. The fire underwriters, the speaker believes, are in print to the effect that if more than eight sprinkler heads are called upon the building is pretty sure to burn. The speaker was grossly misquoted by the fire underwriters' organization last year in regard to this, but is going to again attempt to set himself right. Mr. Metcalf gives a capacity to a 4-inch main under certain conditions which we will agree are approximate conditions, of fifty heads. We are strongly opposed to anything larger than a 4-inch connection, except as Mr. Metcalf modifies it in some conditions; but under extreme conditions, and there have been few cases where we have been convinced that they are entitled to a connection larger than four inches, we have conceded two four inch connections, where drawn from different mains, and where the supply can be drawn from a main sixteen inch or larger, we sometimes permit a six inch connection, although we do not consider this latter good policy.

Mr. Albert Blauvelt: If you have been informed that eight sprinklers ordinarily suffice to put out a fire that can be controlled with sprinklers at all, that in a certain way is correct, because most fires are put out with one sprinkler; but if you wish to insure a low fire cost you must follow what Mr. Metcalf has indicated and be ready with water supply, up to fifty sprinklers.

Mr. J. N. Chester: The speaker cannot recall the name of his authority but is under the impression that some fire underwriter or fire protection engineer appeared before the Pennsylvania Water Works Association at Atlantic City some years ago and stated, generally speaking, that if more than eight fire sprinkler heads were called upon, the building was pretty apt to burn. If the speaker is wrong in his recollection, he would like to know it.

What is the maximum number of sprinkler heads that have been called upon and the fire still extinguished without becoming a

complete conflagration or having to be put out by the Fire Department—where the fire has been controlled absolutely by the sprinkler system?

Mr. Albert Blauvelt: We have on occasions had complete success in controlling fires by sprinkers using as high as 300 sprinkler heads; but these are few. Any competent engineer who is a sprinkler specialist should be able to recommend when he surveys a risk whether the risk will or will not be liable to need the service from fifty sprinkler heads. The modern sprinkler system is commonly regarded as being designed to operate up to fifty sprinklers.

Mr. Henry B. Morgan: On a basis of the statement here made as to fifty sprinkler heads, what size pipe would be required for 400.

Mr. Albert Blauvelt: In good sprinkler practice not more than 200 heads are expected to be exposed at any one fire supplied by a six inch pipe. When you investigate the abnormal cases of 100, 150, 200, 250 and 300 heads fused, you will find a large number of the sprinkler heads opened by heat where there is no fire. The worst case that the speaker ever saw in his life, where a very large number of sprinkler heads went into service and all did work, was a mill at Dayton, Ohio, which was an incendiary fire. The building was on fire on all the four floors and a hole burned through the roof; 286 sprinklers opened, and the fire was so thoroughly spread through the building that in this case all the heads which opened were actually needed. If it had not been for the extraordinary intelligence of the Fire Chief, and a first class steamer pumping from the river as well as the city water, those 286 sprinklers undoubtedly would not have succeeded in holding that building, and in doing so the flow per head was doubtless but a few gallons. As you are all well aware, some water will flow out of an opening under a very low head; a sprinkler is not expected to give good spray service at less than 15 gallons per minute, as mentioned by Mr. Metcalf, yet if a sprinkler head does slop around in more or less efficient fashion at two or three gallons a minute, there is an immense difference between that and no water. When you refer to any size of pipe as related to any particular number of sprinkler heads, we know that putting on an extraordinary pressure increases the quantity of water delivered by any given pipe and this is what was

done at the Dayton fire. It is commonly recognized among sprinkler specialists that whan a fire fuses 50 sprinklers you are getting into a doubtful situation, a situation both rare and extremely inexact. When more than fifty sprinklers are opened there is developed a situation that can not very well be intelligently considered in advance.

Mr. J. N. Chester: Pretty nearly time then for outside influences to take hold.

Mr. Albert Blauvelt: It is time then to push in more water if you have it; but it is quite overshooting the mark to expect in advance that the water department shall furnish so much water.

Mr. J. N. Chester: Would it not be safe to push out more water rather than to push in more water?

Mr. Albert Blauvelt: No, water should always go through a fixed pipe. You cannot reasonably expect water works to fill the entire building with water. The water works should be expected to supply water up to fifty sprinklers, and when that is done all has been done that can be reasonably expected.

Mr. Leonard Metcalf: Might the speaker use as answering Mr. Chester's question the statement made to him by some of the Eastern Insurance agents representing The Manufacturers' Mutual Fire Insurance Company, which as you all know relies especially upon sprinkler systems to do the work, that while it is true that in the majority of fires not over ten to twenty-five sprinkler heads, or perhaps even less than that on an average, discharge at one time, there are many cases on record, the details of which they can give you, in which, as the result of the heat developed in the fire, additional sprinkler heads are opened in the building, and if the supply be limited or be sufficient only to take care of ten or fifteen sprinkler heads, the pressure would be so reduced upon the ten or fifteen heads by the opening of those other heads and by the heat generated, that impaired service would be furnished at the point at which the fire is burning. The fire then would gain headway, and the building would be in a fair way of being destroyed. Therefore experience teaches that while the actual number of sprinklers opened ordinarily is small, it is necessary to have a reserve capacity

in the pipes to take care of the total number of sprinklers that may be open. The speaker understands that there are a good many cases on record where as many as 35 or 50 sprinkler heads have been opened, the cases of from 50 to 100 being rare, the necessity for providing more than fifty depends essentially upon the character of the risk and its environment; so that the authorities are loath to lay down the rule that 50 sprinkler heads is a safe maximum, and this is certainly a fair position for them to take.

Mr. J. N. Chester: Nobody ever asks for less than a four inch connection.

Mr. Leonard Metcalf: That is true. In fairness to some of the insurance engineers it ought to be stated that they take the position that in a congested or thickly built up district it is not desirable to exceed a pipe diameter of four inches, but that it is desirable to employ a number of connections where they can safely be used, rather than to increase the diameter of the pipe.

Mr. J. N. Chester: In regard to the safety of these factories or protected risks being a benefit to the community as a whole, there is no use to argue, we will all admit that; but few of those of you who have sat in the administration office of a water works have not been face to face with the real estate promoter who comes in with a tract of land, maybe inside of the city limits, or just outside, and wants you to extend a main out there before a single house is erected and who tells you that if the main goes out there there will be dozens of houses built and that it is to the community's interest that that tract of land be opened up. No doubt not a single one of you ever attempts to argue with that real estate man that it is not to the community's benefit or that the benefit to the community from that new addition to the city is just about the same as the addition of a factory to a community, and in no case do you lay down a main to furnish a new addition with water because it is indirectly a benefit to the community; you assist those people when you can for your own benefit. According to the same line of argument you should assist the factory because it is going to give employment to a large number of citizens, when by so doing it adds directly to the revenues of the water works or department.

Mr. Carleton E. Davis: The speaker was much interesed in the paper by Mr. Thomas. Philadelphia for the past two months

has had an increase in its typhoid rate. In April and May this rate reached a point about as high as is ordinarily expected in the vacation period of July and August. The additional cases were confined to the district along the Delaware River water front.

This district is supplied by water from the Torresdale filtration plant which also furnishes water to other portions of the city which were entirely free from any increased typhoid.

The Department of Health made a very careful investigation of all possible sources of typhoid and could find no unusual conditions. The customary analyses of the water at points throughout the distribution showed in the general area of the typhoid, the periodic presence of coli in 10 c.c. and rather abnormally high counts of bacteria.

An investigation of manufacturing establishments along the Delaware river water front disclosed the existence of a number of cases where contaminated water from the Delaware was separated from the filtered water by a single check or stop. Steps have been taken to remedy this condition, and in general the managers of the manufacturing establishments have coöperated willingly to eliminate the possibility of contamination. One large firm voluntarily made a complete severance of the water from the two supplies so that they might be entirely above suspicion.

Mr. Wirt J. Wills: The speaker has greatly enjoyed the papers that have been read here by Messrs. Metcalf, Miller and Thomas; but as the gentleman from Milwaukee said, we have been threshing this out for five or six years and we are no nearer to a conclusion than we were when we started. We have just installed a fire protection charge in Memphis which is a little different from that of some water works. We are the largest artesian water works in the United States, and the speaker made a report of some of our rates here last year; on returning home we modified those rates but met with opposition in attempting to get the city to pass the necessary ordinance amending the rates, this opposition coming from the Secretary of the Commercial League. This organization got very busy and collected from all over the United States a list of some two hundred water works that never had made any charge for fire protection. The speaker said to one member of Council, "I can hardly see how a man running a water works, whether a municipality or for private gain, can fail to charge for fire protection any more than he could for water that a man

uses in his boiler." If all these people that think the other way would touch elbows with the man in the ditch, or the fellow that runs the water works, they would be more of that impression. But there being no unanimity of expression with regard to this charge for fire protection, it is pretty hard to get at it.. But Mr. Metcalf says that the thing to do is to put on a detector meter. The speaker suggested that first, but everybody threw a fit at the idea of paying $300 or $400 for a meter for fire protection; consequently in order to meet the situation satisfactorily the speaker suggested that every fire line should be separate and distinct from every other line to the building and be sealed, with a by-pass cutting off the water for domestic purposes, or they could put on a detector meter; otherwise how is the water department to be kept from being robbed? It is not a pleasant thing to cast any reflection upon anybody who represents some big organization, but it does not follow that such an official understands the water works business; on the other hand the water department must see to it that no opportunity is afforded for stealing water out of fire lines.

The speaker is not sure that he knows the best way to do this, but he is quite certain that the water department is often the loser through this kind of a leak. Our charges for sprinkler services are:

600 sprinkler heads or less, 4 inch line, 6 cents per head.

1 cent additional per each head over 600.

6 inch connection, 8 cents for 600 sprinkler heads, or $48 minimum.

$1\frac{1}{4}$ cents per each additional head over 600.

When these rates were put in force there was strong opposition from the large concerns, because the former rate was $37.50 flat charge.

The speaker was greatly surprised at the large number of replies which the opposition at Memphis received from members of water works associations which assisted their contention there, notwithstanding the attention of our members has been called to this matter year after year, and the speaker would suggest that it would be a good idea if the executive committee would try to arrive at some standard conclusion as to charges that would be proper for this service of fire protection.

The speaker can not understand why there should be the same rate for a two inch service in one city as is charged for a six inch service in another. There are many cities that do not allow larger than four inch for this purpose. It would seem that the necessity

for sprinkler systems is just as great in the cities that use small pipes as those that use large. This may not appeal to some people here.

Mr. Henry B. Morgan: The speaker agrees with the previous speaker perfectly. In plants owned by private individuals a charge must be made for this service, and plants municipally owned should also make a charge for it. There is nothing that you can furnish free that the speaker knows of; if John Smith gets his water for nothing, Sam Jones must pay for it. We have a large factory in our city, manufacturing engines, threshers and farm machinery. They have had for several years an eight inch main running into their grounds, making no use of it. It was put there originally, it is presumed, for a fire system which they did not install. Recently they wanted to install a sprinkler system. Their buildings are brick, with clay floors and steel roofs. The Insurance Companies require them to place a sprinkler system all through that building, which is some 500 or 700 feet long. They asked for two eight inch mains, one for each end of the building. They said the insurance company demanded this installation, the speaker told them that he was somewhat surprised that the insurance people did not want four such pipes instead of two, and the speaker is therefore a little bit surprised to hear an insurance man here say that his company was satisfied with a four inch main. They never said so in our city.

Mr. Albert Blauvelt: There is a class of men termed fire protection engineers, or fire protection specialists, to whom the insurance companies look for details of these special installations; but as Mr. Metcalf has remarked the subject is in a very loose state. The speaker pleads an alibi on this particular matter of an eight inch connection.

Mr. Henry B. Morgan: Who are these specialists, do you mean insurance people, or manufacturers of sprinklers, or water works people?

Mr. Albert Blauvelt: Any remarks made on the floor of this convention are made as a member of the American Water Works Association.

Mr. Henry B. Morgan: Water Works managers, people who handle water works, it seems to the speaker, should have some-

thing to say about these things. The managers of privately owned plants have to contend with most of the opposition that arises in the assessing of fair rates for this service. The speaker would like to ask Mr. Metcalf what his opinion is as to limiting the size of pipe to be put into a factory situated in an isolated location between two towns, with nothing around it?

Mr. Leonard Metcalf: In answer to Mr. Morgan's question, generally speaking, in a built up district or congested commercial district it is desirable to limit the diameter of connections to four inches. As you get further out to the isolated risks, while in many cases it will still be desirable to limit the diameter to four inches, and increase the number of connections rather than to use pipes of larger diameter, yet there are cases where it is desirable to increase the diameter to six inches, perhaps a considerable number of such cases taking the country at large, although not many cases in any one small community. The cases requiring a pipe eight inches in diameter would seem to be rare, and larger than that very exceptional.

The reason for requiring a pipe of larger diameter on the outskirts, at the end of a long pipe line, in the case of an isolated risk where it might safely be used, is the fact that the frictional resistance to be overcome is much greater; again when you begin to draw water in any considerable quantity the fall in pressure is much greater than in the heart of the city, so that the available pressure for operating the sprinkler heads in that isolated risk is much less than in the heart of the district, and the only way to overcome this and give better service to such a risk is to increase somewhat the pipe diameter; and this may be safely done in that district where it could not be safely done in the heart of the city, because the actual quantity of water which will be drawn by a six inch pipe in that isolated district will be no more than would be drawn by a four inch pipe in the heart of the business district.

Mr. Wirt J. Wills: The request was made of the Memphis Water Department for a six inch main right in the heart of the town.

Mr. Leonard Metcalf: That in the opinion of the speaker is a mistake. The speaker would like to be permitted to answer one or two other questions in order to make himself clear, not desiring to be misunderstood. With regard to the use of a detector meter or similar device, it is desirable from the community's viewpoint

in a majority of cases, in all except the small risks, and this statement is predicated upon the previous one that the fire protection service should be absolutely separated from the commercial services within the property. The statement that absolutely all fire risks, or risks having fire protection services, should have a detector meter or similar device, seems to be stating the case more broadly than necessity requires, and this with full recognition of the abuse that has existed in many cases. The speaker is a believer in the use of the detector meter in a great many cases, and his only regret is that its cost is so substantial a factor as it is, because if it were cheaper it would be desirable on substantially all of these services.

In regard to the desirability of using a double check valve, this decision must be reached after very careful consideration of all the local conditions. Health should unquestionably be first taken into consideration. If you have a city supply used as a primary supply, not as a secondary supply, but as a primary supply, and a secondary supply which is reasonably safe, it would seem that there should be no question but that a double check valve, with proper inspection at stated periods by water works departments as well as by insurance agents, might be adequate, particularly in those cases where the pressure maintained on the risk side of the check valves is less than the pressure maintained in the city mains. If you have, on the other hand, a secondary supply, or even a primary supply, taken from such a stream as Bubbly Creek, undoubtedly you have no right to take the hazard of installing even a double check valve system, because the dangers of injury to the public are altogether too great; so that you must take into consideration in making your decisions, first, the question of the character of the primary and of the secondary supply, admitting always that it is desirable that the primary supply should come from the pure public supply; second, the relative pressure maintained on the two pipe systems; third, the character of inspection which you can be sure that you will get.

As to the effect of corrosion on the check valves, it would seem that that is met by inspection. If you have periodic inspection, the inspectors must know what the condition of the valves is; but even in that case, if the secondary supply is much polluted, the speaker would not want to rely upon a double check valve.

Mr. Chester surely does not wish to imply that either Mr. Erickson or the Wisconsin Commission predicate rates upon benefits received. Have not Mr. Erickson and the Commission both taken

the position that the rate should be predicated essentially upon the cost of the service? Is that not the case, Mr. Miller?

MR. W. E. MILLER: Yes, sir.

MR. J. N. CHESTER: Mr. Metcalf, do you not think that the water company should be paid for private fire protection service in order to carry out the inspection?

MR. LEONARD METCALF: It was stated in the paper that the author believed that private fire protection service should be paid for, and that regular inspections should be made.

MR. DOW R. GWINN: The speaker will call your attention to the following excerpt from the 1904 Proceedings of the American Water Works Association, at pages 47 and 48, as follows:

> First: That since the protection afforded by private fire lines is a valuable consideration, and since they, in a measure, affect the efficiency of the water works in fulfilling its duties to the general public, in case of a general conflagration, the service so rendered should be paid for by the owners of the property so protected, and the appliances for introducing and measuring the water should be paid for by said owner, just as much as piping, hydrants, and sprinkler heads inside of the building or on the property.
>
> Second: That since the tendency throughout the country, and the decision of some courts, seems to be to throw responsibility for losses by fire upon the water works of the various municipalities, we deem it very important that no contract for supplying water for private fire protection should be entered upon without a clause adequately protecting the water works company or department from damages, if any exist, that may arise from the deflection of the water supply from the private property for the public welfare.
>
> The public weal is of greater moment than that of any private individual, and its demands on the duty of the water departments to comply with them should never be placed in jeopardy for the sake of private interests.

There are several other questions that have come up for consideration, among them that of the four-inch limit. In the city of Terre Haute there is a rule that there shall be no service pipes larger than four inch, though in extreme cases larger sizes might be used, but not for private fire protection. Recently, a six story building was erected for a wholesale notion concern, and when the insurance people were called upon, they specified a two inch connection. Imagine the surprise. But, that was really all they needed, because they had provided a tank on the roof and an electric pump in the basement, and they were well protected.

Public health is a matter of vastly greater importance than that some property owner should save a little money by having connection with the public water mains. If money must be saved, save it in some other way than by jeopardizing the public health. Not only is the public health in jeopardy, but the whole general fire protection system of the city is endangered. The time is coming when automatic sprinkler connections with the public system will not be permitted. A broken sprinkler pipe would so reduce the pressure, where the direct pressure system is in use, as to endanger the entire fire protection system of the city, and the interests of the insurance companies would be at greater risk in the general hazard than they would have been by the fire hazard of the plant with the broken pipe.

Surely, the public health is of greater importance than economies to any individual. Under no circumstances should a connection between a polluted source and a general water supply be permitted.

With reference to detector meters, a four-inch detector can be purchased for $175.

Mr. J. Walter Ackerman: Just before leaving the city of Auburn to come to this convention the erection of a new mill in the town of Auburn was completed and the speaker had called upon the proprietor in relation to the laying of a main for fire protection; he had also had some telephone conversation with the proprietor, who informed him that the insurance people insisted on an eight inch connection. The speaker did not understand why an eight inch connection was necessary and requested the factory owner to write back and find out why such a connection was necessary, because two other larger mills there had a six inch connection which the speaker thought was ample for the purpose. The factory owner got a letter back from the insurance people in which they insisted on the eight inch connection or they would not accept his risk. The speaker wished to know if any insurance representative present could tell him why such a demand was made?

Mr. Albert Blauvelt: The speaker's work with the insurance company simply requires him to inspect plants and advise them whether the risk is good or bad. It therefore did not make any particular difference to him what the arrangement in any given case might be. In his opinion about eighty per cent of the sprinkler equipment in the field is not involved in this discussion today

at all, because it does not use the city water. Isolated risks for the most part do not use city water. The sprinklers in the city of New York and Chicago do not use the city water, for the reason that the pressure in those cities is too low to be available. The sprinkler risks that do call for city connections are those which are located where they can get, or at least try to get, water of sufficient pressure to answer the purposes of the supply; and there is no reason for making such an application except as the supply may be had more cheaply thereby. In the case referred to by Mr. Gwinn where they were satisfied with a two inch connection it was simply asked for as a storage matter not as a supply for the automatic sprinkler equipment. One thing that the speaker thought all interested in this subject could to advantage bear in mind, as stated by Mr. Metcalf this morning with a great deal of diffidence, the present speaker will confirm without any diffidence because he knows that Mr. Metcalf's statements were correct, namely, that automatic sprinkler equipment and the accessories which go with it to make up what is termed modern fire protection costs from three to five per cent of the value of the property protected. There is a reason for the three per cent, and there is a different reason for the five per cent. The reason that it does not run below about three per cent is because no matter how large the property is the irreducible cost of the protection and its accessories runs above rather than below three per cent. The reason that similar fire protection very seldom runs over five per cent is simply because at about five per cent the fixed charges on the investment become such as to just about offset the reduction in the fire insurance premiums. The fact that the fixed charges on the investment exceed the reduction in the insurance premiums until after a high range of values is reached, roughly speaking $100,000 to $200,000, shows that the class of property owners who represent this form of protection are property holders of the larger moneyed class. In short, it is a rich man's game. As has been remarked on the floor here by a number of speakers this morning, the water works officials find that they pretty nearly have to give these owners of sprinkler risks what they ask for.

In a paper delivered before the American Society of Mechanical Engineers last month the speaker made the statement that the large connections inside of the buildings in a number of our cities were just about numerous enough to cripple the entire public supply of the city at a time of conflagration. Of late years there has

been quite a strong tendency to obtain at least part of the advantages of automatic sprinkler equipments and do it more cheaply. The little fellows are getting more and more anxious to enjoy the benefits that the big fellows are enjoying, and for a great many reasons it is very desirable that they should succeed in so doing. But on the other hand, cheaper sprinkler equipment will mean a very great deal more pressure put on the water works for connections, because the water works is the easiest and cheapest source of supply that can be had. It is a question whether the present tendency will not lead in the cities to a state of affairs that large connections will be so numerous as to convince every one that the general water supply of the city is completely jeopardized. The speaker added that he made this statement with great regret, but simply as his conviction that the present tendency is getting worse rather than better.

Mr. William C. Lounsbury: All water works men realize how important this subject is to them, and the fire insurance people likewise. Superior and Duluth are built largely upon the Bay or Harbor, and Superior alone has something like twenty-eight miles of harbor frontage on which practically all the industries of the city are located, and they universally get their water supplies for fire protection from the polluted waters of the Bay. Lately in Superior some requests have been received for direct connections from the public service mains. Last spring a six inch connection was demanded by certain mill people who wanted the end of one of the city mains extended into their property and a direct connection made with their private fire service. At Superior the direct pumping system is in use, and a pressure of 125 pounds at the station is required to be maintained during all fires, thus giving in the center of the business district a pressure of 90 to 95 pounds on the steamers while they are working. In a recent fire, with sixteen streams playing at Superior, a pressure of 95 pounds at times, and at no time going below 89 pounds, was maintained. The question of the size of connections and the further question as to whether connection shall be made with a polluted supply, are vital matters now before the department in Superior. The speaker frankly stated that he was entirely and unalterably opposed to any physical connection between the city pure water supply of Superior and the polluted waters of the Bay. While this may work in some cases a hardship on the owner of the mill or elevator or some large

industrial establishment, it is a hardship that is measured directly in dollars and cents, whereas opposed to that you have the situation that Mr. Thomas so well brought out where the health of the community is involved, which you have no right to menace in any way, because the health or life of any one person or any group of persons, if injured by reason of connecting a polluted with a pure water supply, cannot be measured in dollars and cents.

The speaker does not believe that two check valves are any better than one, on the contrary he feels that sometimes two check valves are twice as bad as one, because when two check valves are installed there is a greater feeling of safety which is not warranted by the facts. The apparent safety is not assured because of having at least two inspections a year. Those water works that have filter plants would not for a moment think of connecting the raw water system through the pumps to the pure water. That would not be tolerated. If there was not sufficient filtered water, the remedy would be to increase the size of the clear water reservoir and the filter plant capacity so that it would not be necessary to have a direct physical connection between the impure river water and the city supply. The public health is very important, and no water works man should for one moment allow any consideration of dollars and cents to influence his conduct in conserving the public health.

As stated last spring, an application for a six inch connection was made by a proprietor on a street on which a six inch water main is located. There was no question of a secondary supply, it was simply fire protection that was at stake. The building was approximately 50 x 120 ft., two stories and a basement. Upon interviewing the men locally in charge of the building they said their instructions were to have a six inch connection made to their sprinkler system. They were told that the charge would be for a six inch service $60 a year, but replied that they did not care what it would cost, the instructions were to get a six inch connection, that a four inch connection would not do, and it was no use to discuss the matter.

Meters should be installed on all such sprinkler systems or fire protection services, or some sort of a measurement device, because it is the experience of every man who has had charge of a distribution system that no matter how many inspections or seals you have, people will make surreptitious connections; whereas if the fire protection systems are to be furnished in buildings, they ought to be for fire protection purposes strictly; their meters help to keep them so.

Mr. A. A. Reimer: The speaker favors a charge for fire protection service, believing that it is a legitimate expense that should be borne by the party protected, inasmuch as it is a special protection. Mr. Blauvelt has emphasized the legitimacy of such a charge when he refers to the fact that it was possible to have so many connections with the public system that in case of a general conflagration the pressure might be materially lowered, perhaps below the actual safety requirements, so that the fire could not be fought successfully; such a condition is not impossible of occurrence. Some terrible conflagrations have occurred within the last twenty years in this country, and others may occur in the future. It is not right to offer an inducement in the form of free service to any of the concerns that request this special protection. Large manufacturing industries are not desirable in all communities. In many localities in this country where manufacturing industries are greatly desired they are constantly being offered special inducements to locate there; but such special inducements, in the opinion of the speaker, should not include free private fire protection services at the expense and risk of the entire community. It is not the proper American spirit to adopt, and charge should be made for such services. Those municipal plants that have no means of enforcing a charge for hydrant rentals are compelled to assume a burden that in the case of private companies is paid for by the tax-payers of the city. Such municipal plants are supposed to pay all overhead charges and operating expenses and show a profit comparable with the profits realized by private companies, yet are not allowed to make a charge for this expensive service. In case free private fire services are granted, the special class that receives such fire protection services is enjoying more than the general public and the water department must bear this additional burden also.

As to the "little fellow" that wants protection, it has been suggested that $100,000 is the limit where the value of the sprinkler system or of special fire protection equipment begins. In some cases the protected value is far less than $100,000, and in some such cases the speaker has been enabled to help these smaller fellows along by using an automatic alarm valve scheme, although for a long time he had refused to accept it, being afraid of it, but was finally convinced after the scheme had been installed in one of the large department stores in his city. It is nothing more or less than a differential pressure valve, properly controlled, so that a slight change in pressure on one side or the other of the valve, automati-

cally accomplishes the ringing of a loud bell outside of the building where it must attract public attention.

The speaker made one demand on the party putting in the first installation of this kind, that the water from the alarm device be run through a glass tube about five feet long and two inches in diameter, so located that every time the meter inspector makes his rounds to read the domestic meter in the store he has to pass by this section of glass tube and can see if any water is running through it. All water that runs by the alarm valve has to pass out through that particular glass tube; so that with the monthly inspection, not an inspection made once or twice a year, but a monthly inspection, there is excellent protection against the illegitimate use of water. The speaker does not assert that this device is going to take the place of the detector meter. He uses a number of detector meters in other installations, but in that particular case, and others that are coming up now for approval, he has found that he can use that particular device so that the benefits of the private fire protection scheme, such as a sprinkler system, can be enjoyed by the fellow who has perhaps only a twenty-five thousand dollar property to be protected, instead of one hundred thousand dollars. The cost of this alarm device is much less than that of a detector meter.

Mr. C. D. SeCheverell: Charging for fire protection presents a different aspect in the case of a municipal plant from what it does in a private plant. In the case of a municipality, a deficit in the operation of the water department is made up by taxation. These private systems, as pointed out by Mr. Miller, lessen the water department's expenses by extinguishing the fire soon after it is started and preventing its spreading. The department is relieved from maintaining the increased fire pressure and pumping the large volumes of water otherwise necessary to put out the larger fire. As the cost of all this is borne by taxation, the community is interested in the best sort of fire protection that it can get. It is assumed that the entire community is participating in the cost and benefits of the service.

In a great majority of private plants the hydrant rentals do not pay the cost of the service. As the Railroad Commission of Wisconsin has determined in this state in many instances it falls short. In one particular case, with the operating expense of the general fire service $42,000, the revenue from the city is only $28,000, leaving a $14,000 deficit that the city does not pay, this being the full

cost of the fire protection. In that case the private plant is justified in making a charge for this private fire protection; whereas, in the case of a municipally owned plant, such as they have in Milwaukee, where the commission has ruled that they shall not make such charge, they are justified there, because the entire expense is borne by the taxpayers, and the commercial consumers are paying only their proportionate cost, and are not paying any additional cost for the general fire protection of the city.

Mr. John Caulfield: With relation to the rates that a municipality should charge for this kind of service, the speaker will take exception to the last speaker's statement. There has been a decision of the Minnesota Supreme Court to the effect that the city of St. Paul was entitled to make a charge, because the service was a special one and the consumer was given a special privilege. As to the amount of the charge, it decided that it would not go into that question and that that might be a matter for future consideration.

The speaker was much interested in the paper submitted by Mr. Metcalf, especially that part relating to the percentage of cities that had replied to a circular asking for information, and the speaker noted that in one case a department had a rule allowing the amount of water used through a meter on other services to apply on sprinkler charges. The city of St. Paul had a similar rule on account of a number of consumers having wells and who had the water pipes introduced into their buildings only for sprinkler systems. The department made a rule that gave such water consumer a credit on his automatic sprinkler charges for water consumed through the meter, as the department did not desire to penalize those consumers who patronized the department for other water supply, but did want to charge for water for this service to those who took water for fire protection only, the water for general use being obtained from wells. Certain parties, who had only the automatic sprinkler systems, brought suit against the city, claiming that the rates charged for this service were excessive. The Supreme Court decided that the city was entitled to make those charges, but that it was discriminating by giving credit to the extent of the water used through meters for other services, the Court stating that this service was different and that it was a special service. It also stated that the department might just as well give credit to some taxpayer on his water bill because he had paid an assessment for sewer or street grading.

The speaker desires to compliment Mr. Metcalf upon the excellent statistical report he has made, as this association has been wanting reports of this character. Some six or seven years ago the speaker offered a resolution, requiring the secretary to send out circular letters propounding questions to all members on various topics relating to waterworks, the replies to be compiled and digested and again sent to all members. Such a plan would save those connected with water works from replying to an immense number of circulars that are received every year from members of the association on various subjects. In the year 1911 Mr. Metcalf, together with Messrs. Emil Kuichling and Wm. C. Hawley, presented an excellent report on "Considerations in Determining a Reasonable Return for Public Fire Hydrants." The association had never had anything along that line before. The speaker has received probably a dozen letters each year in regard to automatic sprinklers and believes that this is a good work and ought to be continued, and that more of these statistical reports and papers should be prepared annually bearing on all subjects relating to water works management.

The city of St. Paul has over 100 buildings equipped with automatic sprinkler systems and has adopted certain rules regarding the size of pipes. For the past ten years and up to the last one the department had a rule that it would not furnish larger than a 4-inch pipe, but a few exceptions were made in extreme cases, where two or three 4-inch pipes have been allowed for very large buildings, these being supplied from different streets where possible. Many consumers have asked for 6 and 8-inch pipes, but invariably have been refused. The consumers contended that they could not get the benefit of the insurance unless they put in the size of pipes demanded by the insurance people. The speaker spoke to Mr. Blauvelt of the Western Factory Insurance Association with reference to this demand for large service pipes and was informed by that gentleman that the department would not have to comply with the regulations; and he was told that he was scaring the people by telling them that the insurance company would not give them the benefit of low insurance if the pipes the insurance companies designated were not installed. The speaker also stated that the insurance people ought to have engineers connected with their bureau and make a survey of each building desiring this kind of service, taking into consideration the size of the building, the height, pressure of water and the use to which the building is put. The insur-

ance company had a rule that for a certain size building a certain size pipe must be put in, no allowance being made as to whether the pressure was 10 pounds or 100 pounds. The speaker was pleased to learn that the insurance people appear to have receded from their position and are ready to agree that an investigation be made by experts along that line of each particular building desiring this service, and that they have practically decided that a 4-inch pipe is the limit in business districts, except in extreme cases. The speaker was also pleased that the regulations heretofore adopted by the department of the city of St. Paul have finally been approved. The speaker is certain that if the insurance people will accept the benefit of the experience of practical water works managers, they will find that it is better for the insurance companies in general as well as for the water departments. A few years ago Mr. Ellis, of Jacksonville, Florida, in discussing this question, stated that at the time of their big fire they succeeded in keeping up the pressure fairly well until after a certain number of buildings that had fire services had been destroyed, and from that time on the pressure decreased so alarmingly that the department was practically disabled, the result being that the business section of the city was practically destroyed. The speaker has often expressed his conviction to insurance men that in many cities where they have insisted upon these large services, in the event of a large conflagration and the breaking of these services, the valves being where they could not be gotten at, or easily accessible, the result would be, as was the case in Florida, that the pressure would be dangerously reduced and general fire service crippled. The speaker has seen fires in St. Paul where it has been impossible to get within one hundred feet of the fire on account of the heat, smoke and gases of combustion. The insurance men are to be congratulated on at last coming down to practical common sense.

Mr. Wirt J. Wills: The speaker would like to correct any wrong impression with reference to municipally owned plants. The previous speaker stated that the revenue was derived from taxation. The speaker does not know whether that is universally the case, but in the city of Memphis, which is under a commission form of government, the water department is a separate and distinct thing, and the only revenue that is derived by it is from water users; so that if they get their fire protection for nothing it makes the domestic rate that much higher.

Mr. W. E. Miller: Probably very few, if any, of the large conflagrations that have occurred throughout the country have started in plants protected with automatic sprinklers. If the Baltimore fire or any similar large conflagration can be shown to have started in such a plant or such a building, the speaker would like to know it. Out of something like twenty thousand fires that have occurred since the introduction of automatic sprinkler protection, the records show that the average loss by fire and water in such sprinkler protected risks has amounted to about $265 per fire. The records of fires under the sprinkler systems in Milwaukee during the past five years show that the average loss was about $266, whereas the average loss per fire in all cases of sprinklered, and unsprinklered risks, was nearly $500.

The sprinklered fires were in establishments of large value, so taking that fact into consideration, losses in fires occurring in sprinklered plants are remarkably small. Everybody knows that large conflagrations, or fires in large buildings, frequently cost the lives of either firemen or occupants of the buildings. The great saving of human life is testified to by the fact that Chicago requires its theaters to be protected, as was stated in the speaker's paper this morning. The speaker also stated in his paper that the courts held that the interest of the individual or the owner of the establishment is primary and of such consequence as to justify a special charge for that service; but in so holding they seem to underestimate the value, to the public in general, of the automatic sprinkler service. The speaker believes that he has been misunderstood as advocating free service to automatic sprinklered systems. He does not consider it as free service, but rather as a part of the general fire protection, at least, in this Milwaukee case, the conditions of which alone were considered. The speaker's paper was not intended to apply generally. The Milwaukee case has not been decided yet, although Mr. SeCheverell referred to a decision of the Wisconsin Commission in the Milwaukee case to the effect that that service was to be free. The speaker would have you understand that the commission has not yet decided that case, and that no conclusion that has been stated by him is offered as anything other than his own opinion. The commission has not yet in any case expressed its view of that case, except to this extent, that in its decision on the Beloit case it held that the company should no longer charge certain industrial plants with hydrant rental. The commission increased the hydrant rental charges against the city,

and held that an increase of hydrant rental which was a lump sum, and not a price per hydrant, should cover the fire protection furnished to the hydrants in the yards of these industrial plants. That form of service is very closely related to that which we have already been discussing, sprinkler service. Of course that does not necessarily indicate what the decision of the commission will be on the question of automatic sprinkler service in this Milwaukee case. It has been said here this afternoon that there is a decided difference between a municipally and a privately owned water works in the matter of its earnings from hydrant rentals. In the Milwaukee case the plant charge for hydrant rental was $5 per year each. In some years the council canceled even that charge. The railroad commission of Wisconsin in its decisions on municipal water rate cases as well as those involving privately owned plants has always taken into consideration in fixing rates for fire protection and for commercial, industrial or domestic service, the elements of taxes, depreciation and interest on the investment, as well as operating expenses.

The main question which the speaker was considering in his paper this morning was, whether or not the public's proportion of the expense of the plant, including not only operating expense but interest on the investment, depreciation and taxes, should be subdivided between the municipal hydrant service and the private fire protection. The speaker's view is that the service furnished to automatic sprinkler systems should be covered by the hydrant rental. This is simply allowing the owner of the plant protected by automatic sprinklers an opportunity to make more efficient use of a service which otherwise would be supplied only through hydrant and fire department equipment.

With regard to the question of the size of connections permissible: If a water department or a water company adopts and publishes a rule that it will grant no connections larger than four inches or larger than six inches, as the case may be, there will be no further trouble, no further efforts made to get larger connections. It seems that the time is coming when the insurance companies will realize that those sizes are generally ample. The records of sprinklered fires, of which it has already been said there have been at least fifteen thousand in this country, show that only in a comparatively few cases are there considerable numbers of sprinkler heads opened. By the time a fire reaches such proportions as to make any very

large demand on the system, the fire department should be there ready to take charge of the work.

No particularly strong efforts are being made in Milwaukee to get a larger size than four inches, which is the maximum provided in the water department rules, although the rules have practically been changed to allow a six inch connection through the allowance of two fours connected into a six. The speaker does not understand that any efforts are being made to get eight inch connections, or more than two fours into a six inch.

Mr. Wm. Luscombe: It has been pointed out very plainly that fire protection service connections have been abused and taken advantage of in some cases; and the speaker believes that the members of this Association would be very much pleased to have Mr. Miller solve some of the puzzles that they have been up against in combating such abuses.

Mr. W. E. Miller: The speaker believes that he answered that question in his paper this morning by making it clear that he was referring to metered service only. He endeavored also to make it plain that he would be in favor of a flat rate charge for unmetered service to cover the cost involved.

President Gwinn now offered as the last word on the general subject under discussion a number of citations from legal authorities, extracts from opinions and decisions, etc., in private fire protection cases, as follows:

CITATIONS FROM VARIOUS LEGAL DECISIONS, ETC.

"A water company which supplies the pressure and water for an automatic sprinkler for a private corporation performs a service which is not included under its contract with the city to supply water for fire protection, and has the right to make a reasonable charge therefor against the corporation."

D. B. Loveman Co. *vs.* City Water Company, 1 Tenn. Ch. App. 596.

"The benefit received was not incidental, but it was the result of a direct appropriation by the furniture factory of power and water, which was the property of another, as a standing guard over its property against peril or destruction by fire. Connection with a light or water plant accompanied by the asserted right of using it and the means of exercising the right is a benefit enjoyed at the hands of another imposing an obligation to make reasonable compensation, although the occasion for actual use never arises."

Cox *vs.* Abbeville Furniture Company, Supreme Court of So. Car., Aug. 9, 1906.

In the case of Shaw Stocking Company *vs.* City of Lowell, 85 N. E., 90, the Supreme Court of Massachusetts said:

"The defendant's duty to supply water at reasonable rates to all takers without discrimination, so far as this duty exists, does not carry with it any obligation to supply water free of charge for the plaintiff's private system of safeguarding its property."

In the case of Gordon, et al. *vs.* Doran, 8 L. R. A. (N. S.), 1049, the Minnesota Supreme Court said:

"So long as water supplied for protection against fire is a purely public service under the control and management of municipal authorities generally, and under the fire department specifically, no direct charge to individuals is proper. When however, a sprinkling connection is made with private premises, the situation is materially different. These premises and the primary causes of catastrophe to the building and of the constant possible use of disastrous quantities of water, are primarily under the control not of the public, but of the owner. A peculiar personal service is provided for his benefit, which is not enjoyed in common by the community in general, but is available only to a limited class of individuals. It does not advance the reasoning in this connection to split hairs between the 'use' and 'the consumption' of water, and as a matter of good sense the property owner beneficially employs the water mains for his own purposes, and to his own advantage, although he may not, except in case of fire, actually draw any water from the pipes. It is necessary and proper that for this he should pay. In fact he gets something of pecuniary value from another, which that other is not compelled to give except on the basis of contract."

The following are interesting cases on the general subject here treated:

Shaw Stocking Co. *vs.* City of Lowell, 85 N. E., 90;
Cox *vs.* Asheville Co., 54 S. E., 830;
State ex Rel. *vs.* Gosnell, 61 L. R. A., 33;
Gordon *vs.* Doran, 8 L. R. A. (N. S.), 1049;
Am. Mfg. Co. *vs.* City of New York, 94 N. E., 1091;

"In all cases where a factory owner desires service through a large pipe, such as is demanded in this case, a requirement that a meter be installed at the cost of the consumer may be enforced even though the ordinary consumer of water is not required to use a meter. This has been expressly decided and there is no authority holding to a different view."

State ex Rel. *vs.* Gosnell, 61 R. A., 33.

"A contract by a water company to furnish a town with water providing for a supply 'for domestic purposes, the extinguishment of fires, and other lawful uses' and also 'for public and domestic uses and purposes of inhabitants' of the town did not authorize the corporation to furnish water for the driving of printing

presses, fans and other mechanical purposes, nor to supply railroad engines to the prejudice of the inhabitants of the town for domestic and fire uses."

Town of Boonton *vs.* Boonton Water Co., 61a, 390, 69 N. J. Eq., 23, Affirmed;

Same *vs.* Water Supply Co., 64-a 1064-70 N. J. E., 692, 73 N. E. 558; 69 L. R. A., 309; 41 S. W., 911.

"In the matter of furnishing water to its citizens, a city when authorized by its charter acts in a private rather than a governmental capacity and has the same right to make reasonable charges therefor that a private corporation has when serving the public."

St. Louis Brewing Assn. *vs.* City of St. Louis, 140 Mo. 419; 37 S. W., 525; 41 S. W., 911.

"A rule providing that water meters might be installed at the pleasure of the water board and the consumer, and that, after they had once been installed, the consumer could not thereafter return to the flat rate is reasonable and may be enforced where the meter rates are reasonable and no discrimination between the consumers is shown."

Powell *vs.* Duluth, 97 N. W., 450.

"Requiring hotel proprietor to install tanks from which to take water for operation of elevator instead of taking direct from main held reasonable in view of effect in change of pressure on system."

Kimball *vs.* North East Harbor Water Co., 78 A., 865.

Opinion of Vankirk, J., in the case of Julius P. Baumann and David K. P. Baumann, etc., *vs.* Samuel D. Kendrick, et al., composing Board of Water Commissioners, City of Glens Falls, Warren County, New York:

"Under the charter the City of Glens Falls, the Board of Water Commissioners adopted Rule 22, viz., large connections for fire protection by means of automatic sprinklers or standpipes will be allowed only on written application to the Board of Water Commissioners, and all said applications must be made at least thirty days before the connection is made. All such services shall be metered, and the size of the meter shall be the same as the diameter of the pipe requested. The charge for such connections shall be as follows: Three inch, $210; four inch $300; six inch, $500. No further charge will be made for the service unless the meter shows a draft of water at a time when there has been no fire, and in such case the established meter rates shall be charged for the consumption, and the right is reserved by the Board of Water Commissioners to shut off the supply entirely."

The Court says:

"To protect against the unauthorized use of that water through this connection, the meter is a proper instrument. There is no sufficient reason why the Board should not be permitted to have the water drawn through this connection

for the sprinkling system measured, if it has authority to so require it. Section 96 of the Charter gives the necessary authority. There is no good reason why the cost of the connection and of the meter should not be paid by the property owner benefited. There seems little fairness in demanding this other use of the water for special fire purposes and also demanding that the city bear the expense of putting it in, or of the meter to guard against unauthorized use of water through this connection. The city is under no obligation to furnish plaintiffs water for such special purpose; and the owner may exercise his choice whether or not he shall use it for such purposes."

TURBINE PUMPS FOR THE MINNEAPOLIS CITY WATER WORKS

By Edward P. Burch

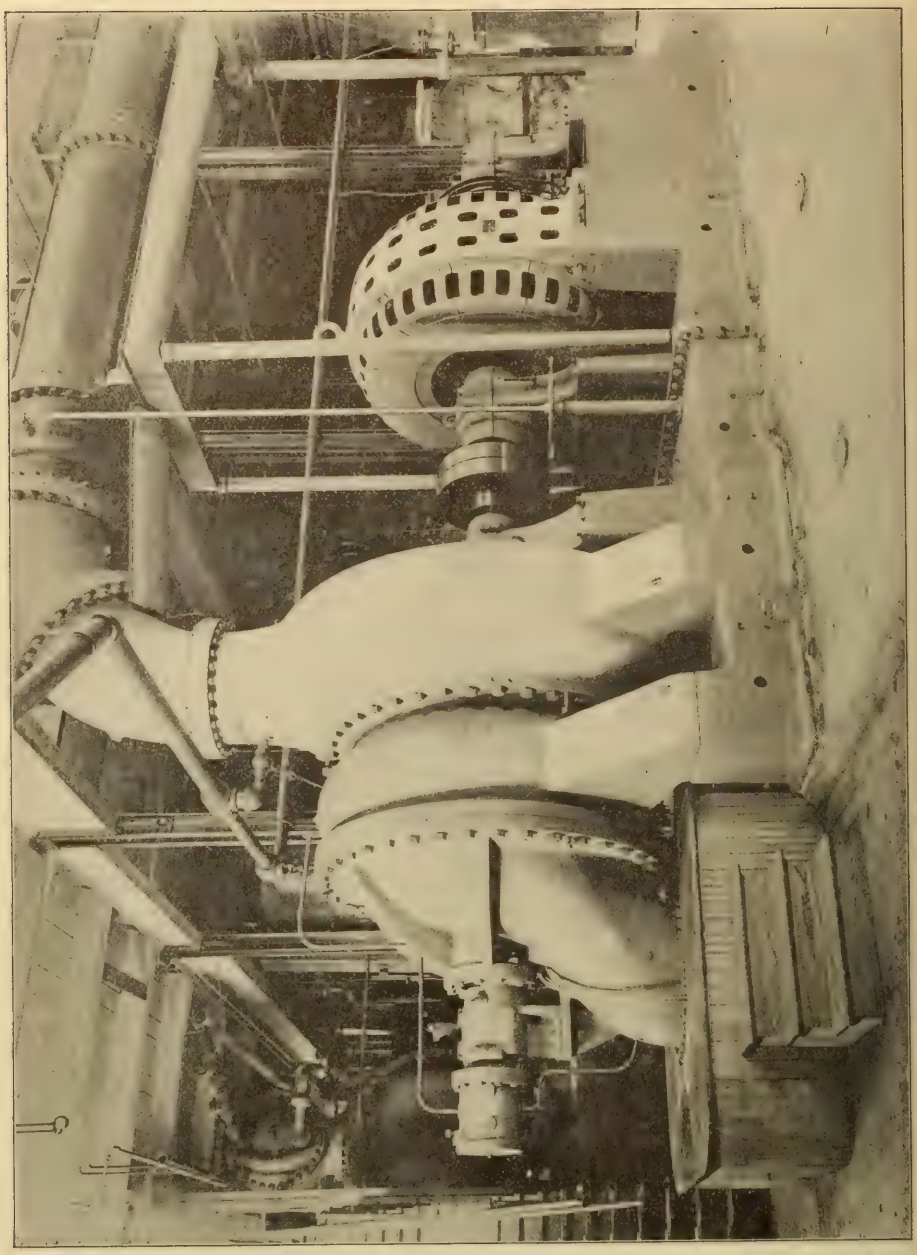
Technical data for two 20,000,000 gallon turbine pumps, installed in the Minneapolis water works plants in the spring of 1912, which since that time have pumped over 99 per cent of the city water used for domestic and fire service, are presented herewith.

Minneapolis city water pumping plants are about 1300 feet apart on opposite sides of the Mississippi River, about four miles north of the city hall. The old steam plant, at Camden Park, is no longer used. It was constructed in 1889 on the west side of the river, and contains 4 marine type boilers and two 10,000,000 gallon Worthington horizontal steam pumps. The Northeast plant, completed in 1904, is on the east side of the river and contains four 200 horse power water-tube boilers, and two 15,000,000 gallon Holly vertical triple-expansion steam pumps.

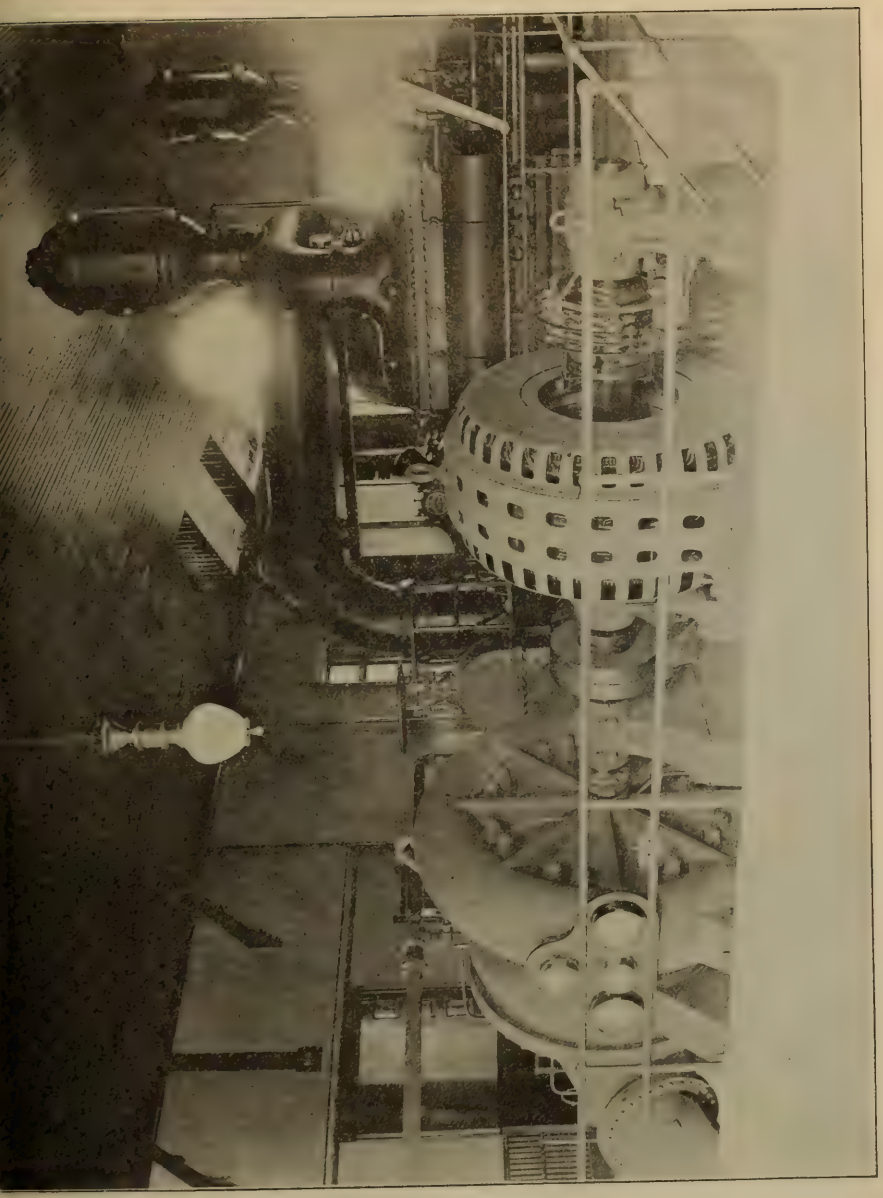
One 20,000,000 gallon horizontal motor driven turbine type pump was installed in each plant in 1912. Energy for driving the electric pumps is derived from a water power plant on the St. Croix River, 44 miles from Minneapolis, the power being purchased at the pumping plant on an "off-the-winter-peak-load" basis for $4 per million gallons at 240 feet head and 72 per cent pump and motor efficiency. This rate is equivalent to 38/100 cent per kilowatt hour, or $24.83 per horsepower year.

Pumping service at Minneapolis in 1912 averaged 22,000,000 gallons per day, with a maximum of 46,000,000. The water rate is 8 cents per 1000 gallons, and water is used liberally in summer for lawns and gardens. The water consumption in 1913 has been rapidly increased by the rapid growth of the city, and the extra wash water used at the new filtration plant. This plant was described by J. A. Jensen, Minneapolis Water Works Engineer, in the *Engineering News*, June, 1912; also by Mr. W. N. Jones at this annual convention.

The water is pumped to the filtration plant reservoir, the surface water of which is about 235 feet above the surface of the river. The pressure line is a single 50 inch steel pipe, 19,000 feet long,



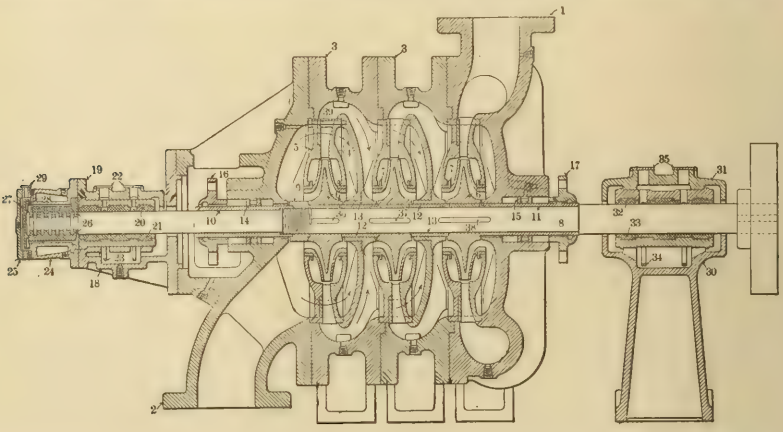
PUMP AND MOTOR IN THE NORTHEAST STATION



PUMP AND MOTOR AT THE CAMDEN PARK STATION

installed by Mr. F. W. Cappelen, City Engineer, 1896. A second 54 inch steel pressure pipe is now being installed.

The head pumped against corresponds to the difference in levels between the filtration plant and the river, about 235 feet, plus a friction head through the 50 inch main of 16 to 18 feet when pumping at a 24,000,000 gallon rate or with one electric pump. The friction head with the two electric pumps, each working at a 20,000,000 gallon rate is normally 37 feet at either station, thus making the ordinary dynamic head in pumping service about 272 feet. Recently, however, with 48,000,000 gallons total output from two electric pumps and one steam pump, the friction head has been 52



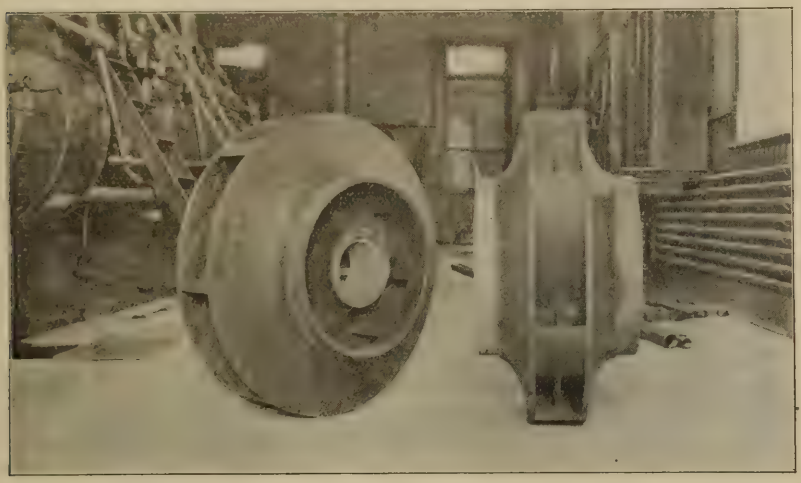
Sectional View of a Double-Suction Impeller Three-Stage Turbine Pump

feet and the dynamic head 287 feet. When the second 54 inch force main is laid between the pumping plant and the filtration plant, the normal friction head will decrease to about 12 feet, making the total head, at a 40,000,000 gallon rate, about 247 feet.

Specifications for the turbine pumps, prepared by the writer, as consulting engineer for the City of Minneapolis, called for two 20,000,000 gallon electric motor driven units for service with the operating conditions above outlined. By design the pumps were to have a maximum efficiency on a 247-foot dynamic head, the future ordinary operating head. On this head each pump was to deliver water at the rate of at least 20,000,000 gallons per day. With the ordinary maximum summer service, about 40,000,000 gallons per day from two electric pumps, the maximum dynamic head until 1914 will be about 272 feet, under which head the gallon

capacity was to be well maintained. In the design of the pump itself, no rigid limitations were placed on the impeller, diffusion rings, stage detail, hydraulic or mechanical parts, these being left to the manufacturer's designer, and stress was laid on the results to be accomplished, and the maintenance of a high efficiency and of the gallon capacity, on the widely varying heads.

Specifications for the motor required a horizontal direct-connected, 3 phase, 60 cycle, 2200 volt, slip ring induction type, of 1200 horsepower capacity, with minimum speed change from no load to full load, capable of starting the pump from rest, when the pump was primed and when the check valve in the discharge was



Bronze Impellers of Turbine Pumps

closed, without drawing more than 150 per cent of full load current from the source of supply. The switchboard panels specified were to contain the indicating, curve drawing and integrating meters, safety devices, and controllers which were needed for metering and checking the watthour input, and for the intelligent operation, control and protection of the service.

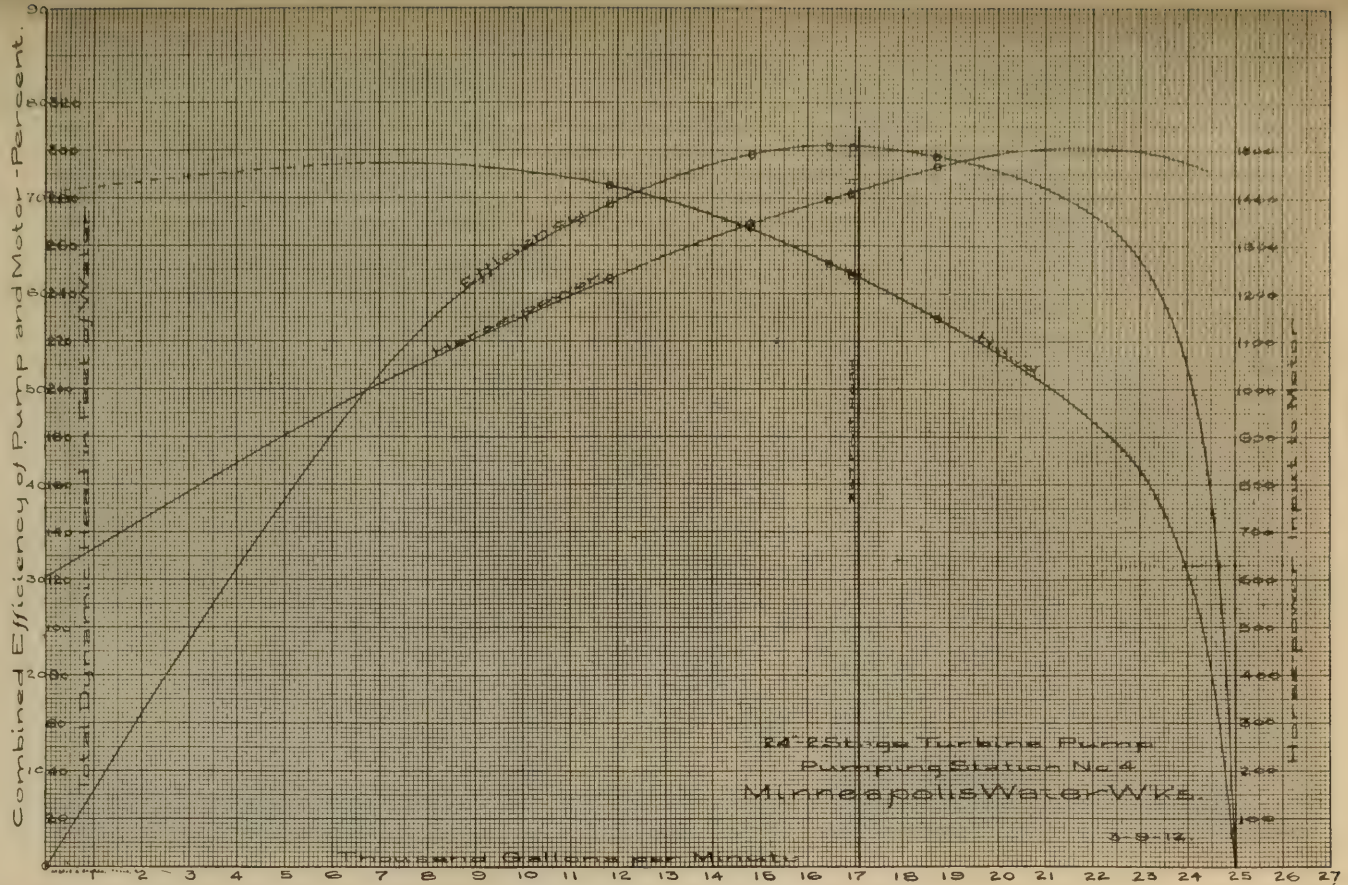
Proposals submitted by the six leading pump manufacturers were accompanied by a description and outline drawing of two stage pumps running at about 600 r.p.m., and a diagram and table showing the guaranteed capacity of the pump on different heads, and the guaranteed efficiency of the pump, with dynamic heads varying from 240 feet to 275 feet. Pumps with diffusion rings and guide

vanes and those with double suction or balanced impellers showed the highest efficiency. Horizontal split pumps seem to offer the best facility for repair and maintenance work, but it was felt that the splitting of the bushing rings was a bad feature. These bushing rings are mounted on either end of the impeller hubs, and separate the several stages of multistage pumps, and it is essential that the fit be tight to prevent the leakage of water, and loss of energy and efficiency in such high pressure pumps.

A contract was let whereby the guaranteed combined efficiency of the selected pump and electric motor at normal head was the highest, 75 per cent; because the efficiency was maintained over a wide range of dynamic head; because the falling off in capacity on the higher head, 275 feet, was a minimum, and further because the two stage pump offered had double-suction impellers with inside passage ways between the balanced impellers. The contract was based on the combined pump and motor efficiency, in order to avoid any shifting of responsibility by independent pump and motor contractors. A bonus and forfeit for higher or lower efficiency than the 75 per cent were provided for in the contract.

Preliminary tests showed, as was anticipated by the manufacturer, that at normal head the gallon capacity of the pumps was about 24,000,000 gallons, or 20 per cent more than called for by contract; and, because the curve of efficiency was not a maximum at the normal operating head, 247 feet, as called for by the contract, the impeller was then reduced slightly in diameter. Provision for such modifications had been provided for by contract. In reducing the impeller diameter about $\frac{1}{8}$ inch, and by changing slightly the angle of the tips, the capacity was reduced to that required by contract. So far as could be determined the maximum efficiency and the general shape of the efficiency curve were not materially altered by any of several small changes made on the impellers of either pump. Extra impellers were purchased for experimental and operating service.

Characteristic curves are presented from the tests made, showing the relation of the capacity in gallons pumped per minute on dynamic heads varying from 295 feet to 230 feet, to the horsepower input, and to the combined efficiency of the 24 inch, 2 stage turbine pump and motor installed at the Northeast station. The efficiency of the pump alone, for a wide range of head exceeds 80 per cent. The pump was designed for 247 feet dynamic head. See Characteristic Curve Sheet 1.



CHARACTESISTIC CURVE SHEET 1

Electric motor tests were also made and showed that, based on the standardization rules of the American Institute of Electrical Engineers, the capacity was about 1235 horse-power. The power factor of this induction motor is 92 per cent; the speed is not reduced more than one half of one per cent between no load and full load; and the efficiency, which is above 94 per cent at normal load, is maintained over a very wide range of load. Starting tests showed, that with the pump primed and the check valve in the discharge closed, the current input was not more than 90 per cent of full load current. Ordinarily, however, the pump is started, after being primed, with the 24 inch gate valve in the discharge pipe closed, but with a 6 inch by-pass opened, and under these conditions the motor brings the pump up to full speed in about 36 seconds without drawing more than 75 per cent of the full load current from the source of supply.

Acceptance tests of the combined pump and motor efficiency were made by checking the kilowatts input to the motor with the gallons discharged by the pump, over the full range of operating heads. The ratio of the output to the input, in proper units, is a measure of the efficiency of the pump. A small bonus was earned by the manufacturer for obtaining an efficiency for the combined pump and motor, which was above 75 per cent. This efficiency corresponds to 94.3 per cent for the motor and 80 per cent for the pump itself.

Details of test for capacity and efficiency embraced:

1. Electric power in kilowatts delivered to the motor was measured by the meters owned by the city, the meters owned by the power company, each calibrated in place by standards furnished by the electrical engineering department of the University of Minnesota.

2. Dynamic pressure on the water was measured by means of duplicate, checked gages on the suction and discharge pipes, corrected for the difference in gage levels, and the velocity heads through the pump.

3. Gallons delivered by the pump were measured by means of a weir box 16 feet wide and 22 feet long, with a weir 8 feet wide. The weir was designed in strict accordance with the rules laid down by the United States Geological Survey in its "Handbook on Weirs," No. 150, of 1906. One hook gage was placed in the weir itself and checked by a hook gage in a glass enclosed, pipe connected water chamber placed outside of the weir box. At the same time a Venturi meter was placed in the turbine discharge and its calibration

WATER DISCHARGED OVER WEIR

WATER DISCHARGED OVER WEIR

curve was obtained from the weir measurements, and is now used as a basis for operating records. The zero point of the weir crest was measured by a surveyor's level. The weir heights were taken in the weir box 11 feet back of the weir. Observations were taken synchronously on speed indicators, electric meters, pressure gages, and weir heights, and each of the four observers furnished the results of their observations for the records. Any readings which were radical, caused for example by a temporary high or low speed of the motor, by agreement among all four observers, were discarded. The test observations were much more uniform than would be expected, because of the simplicity of the observations.

Operating results from the pumps show that during the first year ending May, 1913, they have performed admirably and satisfactorily. On account of the great amount of sand in the water delivered to the pump in the old Camden Park station there has been some wear. The sand gradually cut and scored the bushing rings and thereby caused considerable loss in water between the two stages and, in time, reduced the capacity and efficiency of the pump. One pump impeller at this station, where there is no screen, was damaged by brick or something which tore out a $3 \times 4 \times 5 \times \frac{1}{2}$-inch triangular section in one of the bronze impellers. At the Northeast station, where the water is clear, this trouble did not occur but, after the first year's service, one diffusion ring tip was found to be broken off, thereby reducing the capacity and efficiency of the pump two to three per cent.

The pumpage records for the first year ending May 1, 1913, show:

Camden Park, 1,581,860,000 gallons and 250.46 feet head.
Northeast, 6,783,190,000 gallons and 259.78 feet head.

The average combined efficiency of the pumps and motor was 72 per cent and the average cost of electricity was $4.20 per million gallons. Only one man per shift is required per pump.

The four bushing rings which surround the two impeller hubs on each pump have recently been bored out, then refilled with solder and tin and thus a tighter fit has been obtained, to reduce the leakage of water under pressure between the stages. The lead will prevent a seizing of the rubbing metals. The chief engineer of water works, Mr. E. C. York, who has carried out this work on the first pump, reports that the pump efficiency, as shown by the records for the month of May, 1913, has been raised from 80 to over 82 per cent, and the gallon capacity has also been increased.

Conclusions and recommendations made, as a result of a rather wide range of experience with electric driven, multi stage turbine type pumps, in ordinary city water works pumping service, for small cities with widely varying pressures, are as follows:

1. Turbine type pumps when properly suited to the situation are simple, powerful and reliable; are of low cost, for the pump installation and for the building; give excellent service, and show low cost of maintenance.

2. Electrical energy can be purchased at about one half of one cent per kilowatt hour from large steam or water power stations, if the contract is on an off-the-peak-load basis. City water pumping plants can purchase such energy to advantage for turbine pumps, saving in operating expense, particularly in labor and in maintenance.

3. Where a reservoir is used, the pumps can be kept out of service during the hours of the peak load on the central station in winter, thereby reducing the total cost of boilers or water power equipment required for the combined railway, electric light and pumping plants of the city or territory, thereby making a reduction of the cost of power in the locality.

4. When a steam pumping plant is already installed, additional capacity can be obtained at lowest first cost, by the use of the turbine pump for the building and the equipment.

5. An independent source of power supply for the electrically-driven water works pumps provides one additional safeguard against interruption of pumping service, and in many cases should cause the insurance underwriters to indorse the plan, and reduce the fire insurance premium rates.

DISCUSSION

Mr. John Caulfield: When Mr. Burch made those tests, were the readings on the Venturi meter and the Weir measurements taken at the same time; if so, how did they compare?

Mr. Edward P. Burch: They were taken at the same time. They did not compare very well, because the calibration curve of the Venturi meter, over the wide range covered by these tests, is not a straight line curve.

Mr. Theodore A. Leisen: What was your average efficiency for the year?

Mr. Edward P. Burch: The average efficiency, for the past year, for the two pumps was about 72.5 per cent. The efficiency last month at Camdan Park station was 77 per cent. With reference to efficiency when the pumps were overhauled at the end of the first year's service, it was found that the bushing rings of the pump at Camdan Park station were cut a great deal. These bushings were bored out about one eighth of an inch, were leaded, and since that time the pump has run with much tighter bushing rings, and it has prevented the loss of water between the two stages. The pump efficiency has thus been raised two per cent above what the manufacturer guaranteed. At the northeast station, the efficiency fell below 75 per cent because one of the steel diffusion tips was broken off.

Mr. William Luscombe: Is this pump as practical for water works service, where the head varies greatly?

Mr. Edward P. Burch: No. A variation of over 25 per cent in the head is not desirable unless provided for in the centrifugal pump installation; on the other hand a pipe line which must take care of more than 25 per cent difference in pressure, caused by pipe friction, is not operating under satisfactory conditions or on an economical basis.

Mr. John M. Diven: The question is do you at Minneapolis pump direct into the mains or to a reservoir?

Mr. Edward P. Burch: In case of direct pumping the ordinary pumping pressure does not vary more than 15 per cent.

Mr. J. Walter Ackerman: In direct pumping where you are maintaining a constant head and have no reservoir, you pump direct into your lines; but your rate of pumpage of necessity must vary; that is between your day load and night load you get a wide variation. How is your centrifugal pump going to stand that?

Mr. Edward P. Burch: Centrifugal multi stage or turbine pumps respond well under such wide variations. In Minneapolis the centrifugal pumps may be required to pump at low pressure directly into the main. The capacity of each pump ranges from 28,000,000 gallons with a 240 foot head to 17,000,000 with a 290

foot head, yet the horse power input of the motor does not vary more than 20 per cent. As the head decreases the gallons increase, and vice versa, thus maintaining a fairly uniform load on the motor.

Mr. Earl W. Kelly: Last winter we had a break in our force main between the pumping station and reservoir. We pump with an electrically driven centrifugal pump, capacity 12,000,000 gallons per day. Between the break and the pumping station there is a portion of the city which we supplied, being a comparatively small district, by direct pumping while we were repairing the force main. We pumped with the 12,000,000 gallon pump at the rate of about 2,000,000. It worked very satisfactorily, and the only effect on the pressure was to increase it in that district by about 20 pounds.

Mr. J. N. Chester: Have you the fuel cost? Have you any figures you can give showing the current cost per million gallons?

Mr. Edward P. Burch: The cost of electricity is 38/100 cents per kilowatt hour.

Mr. J. N. Chester: How does the cost as to fuel compare with the old steam pump cost?

Mr. Edward P. Burch: The speaker cannot answer directly on the fuel cost. The cost of electric pumping in 1912 was about $4.40 per million under 250 feet head, for electricity only. There is one man on each shift, for each pump.

Mr. J. Walter Ackerman: Relative to the difference in rate of water consumption, does not the electric motor play a large part in the economy of the subject? Supposing that you were running this by steam instead of by electricity, you would have a very variable rate. Does not your electric motor then show an uneconomical consumption of current out of proportion to the water pumped? Your pumps are operated continuously at a uniform rate per 24 hours, are they not? If not, what is the percentage of variation in gallons?

Mr. E. P. Burch: Last night one pump was running at a 23,000,000 gallon rate; today two pumps are running each at a 20,000,000 gallon rate, making a 40,000,000 gallon rate, or a difference of 70 per cent. In winter the water consumption is less, and

the pumps may not be used during the peak of the load on the electric power station. There is a reservoir of about 50,000,000 gallons capacity used in connection with the pumps.

Mr. J. Walter Ackerman: That does not represent the ratio of the station use as between the day load and night load?

Mr. Edward P. Burch: No sir, the data refer to pumping.

Mr. J. Walter Ackerman: If you had to depend upon this one unit to adjust itself between the day load and night load, would not your electric motor come in there as a big factor as to efficiency? That is, there is some certain point where the motor will run at its best efficiency. When you change its rate of speed does not the efficiency fall off?

Mr. Edward P. Burch: The efficiency of the motor drops off about two per cent between full load and half load. Two motors are desirable, in order to maintain efficient loadings. When a single two speed motor is installed, and used without a reservoir the pump can be used at full speed and pressure for fire service; then when the pump is running at half speed, the efficiency of the motor would fall off more than two per cent.

Mr. William Luscombe: In your experience a centrifugal pump is not as practicable for direct pumping as where you use it to fill a large reservoir under constant head? The consumption in a direct pumping system would certainly vary more than 15 per cent, and in that case, according to your conclusions a centrifugal pump is not practicable for such service?

Mr. Edward P. Burch: In Minneapolis the pumping service on an ordinary summer day varies from a 23,000,000 gallon rate at night to a 40,000,000 gallon rate in the day time or 70 per cent, and in emergencies the variation can be much wider. Now in an ordinary town, without any reservoir, with a direct pumping system, pressure increases at night, while there is a lack of consumption of water, or because the steel tank has been filled, and the rate of water pumping is reduced automatically by the use of centrifugal or turbine-type pumps. In case it becomes necessary to pump at high pressure for fire service, there should be a second pump to

put in parallel or in series with the first pump. The speaker does not know of any case where he could say that the turbine type of pump was not practical for water works service. He cannot say that it is down and out for that kind of service.

MR. WILLIAM LUSCOMBE: The reference was more particularly to where the tank or reservoir was eliminated, and it was a direct pumping system.

MR. EDWARD P. BURCH: In such cases the pressure usually varies about 30 per cent, including fire service; and as the pressure increases or decreases inversely with the rate of consumption the gallon capacity of the two or more pumps decreases or increases automatically.

MR. PAUL HANSEN: Will Mr. Leisen tell us something of the experience he has had with the new centrifugal pump at Louisville?

MR. THEODORE A. LEISEN: During 1912 there was installed at Louisville, Kentucky, as a reserve pumping unit a Thirty-million Gallon Tri-rotor Centrifugal Pump operated by, and directly connected to, a Vertical Steam Turbine instead of an electric motor. There has been no urgent necessity for operating this pump except for test purposes, and so far it has never run continuously for more than a week at a time.

Considerable trouble has been experienced with the stoker and furnace furnished with the boiler which was installed in connection with this pump, and this has interfered to a great extent with the experiments and tests which it had been hoped would have been carried out before this.

Under the specifications the pump was guaranteed to develop a duty of one hundred million foot pounds per thousand pounds of dry steam when operating against a dynamic head of 190 feet and at a speed of 1500 revolutions per minute. During a twenty-four hour test run the conditions of capacity were complied with, the dynamic head was 0.4 of a foot higher than specified, and the speed required to develop the specified capacity was 1418 r.p.m. The duty developed on this run was 108 million foot pounds or 8 million foot pounds above the guarantee, and in computing this duty all steam used by the dry vacuum pump, the step bearing pumps and the condenser hot well pump was added to that used

by the turbine itself. During a ten hour run when operating at its rated speed of 1500 r.p.m. and pumping at the rate of 35 million gallons for twenty-four hours it developed a duty of 110 million foot pounds.

Shortly after the floods of January and March of 1913 the pump was started up, and we were very much surprised and somewhat disappointed and disturbed over the fact that when running at a speed of 1420 up to 1450 revolutions the meter only indicated that the pump was discharging at the rate of about 22 million gallons. The meter was first tested and then the manufacturers of the pump were communicated with, but without waiting for results of their investigation the pump was shut down, and the inlets, outlets and impellers examined, and it was found that eight of the passages through the bronze impellers were stopped up by pieces of timber which had become tightly wedged into these passages and absolutely clogged them. Consequently the capacity of the pump was reduced in almost direct proportion to the number of clogged passages in the impellers. These obstructions were removed and the next time the pump was operated it gave results practically identical with those obtained on the test run.

It is regretted that conditions have been such as to have precluded the possibility of making a long continuous run of the Centrifugal Pump in order to work out a series of characteristic curves under all varying conditions, and it is hoped that this may be done during the present year.

The pump at Lousiville is operated under somewhat similar conditions to the motor driven pump at Minneapolis. The water is taken from the river and pumped to a reservoir, and the head and capacity are practically constant, and these are ideal conditions for a centrifugal pump.

The centrifugal pump is admirably adapted to just such service as it is being utilized for in Minneapolis and as it has been put to in Louisville, but it is not wise to instill in our minds the idea that the centrifugal pump will meet every condition satisfactorily. It has its limitations just as most other machines have,—and more so probably than some other types of pumps.

The installation of the centrifugal unit in Louisville was a particularly economical proposition, because there was already constructed a pumping station that would accommodate this unit, whereas to have figured on a high duty pumping engine it would

have been necessary to expend nearly a half million dollars for the construction of a new building to house it.

Concluding, the speaker does not think that the centrifugal pump is well adapted to direct pumping. Where water is pumped directly to the city without reservoir or standpipe intervening, the variations are not merely of pressure, but of volume. Under these conditions the speaker doubts the wisdom of installing centrifugal pumps in place of direct acting pumps, unless some advances are made in the design of the former type.

THE REFORESTATION AND GENERAL CARE OF WATERSHEDS

By Ermon M. Peck

When our secretary requested the writer to prepare a paper on the above subject, he offered as a prelude the statement that Hartford had done more along this line than any other city in the country.

Than the writer, there is no one more anxious to uphold the fair name of Hartford. He is heard singing her praises always whenever there are any to be sung. But it must be admitted that the 200 odd acres reforested by her water department seems a lilliputian area when compared with the great 1100 acre planting of the Metropolitan Water and Sewerage Board of Boston.

The writer wishes to state at the outset that he is not a practical forester or, in fact, any kind of a forester; and his poor attempt to handle this subject will be entirely from the standpoint of a water works man.

With possible slight exceptions virgin forests in southern New England have long been a thing of the past. Something approaching this, however, has become apparent during the past century as a result of the abandoned farms and portions of farms for which this corner of the country has become proverbial. No sight is more familiar to our surveyors than that of trees, sometimes of large diameter, growing on fields where the old furrows are still plainly visible.

When our not very ancient ancestors replaced the slow, patient ox with the nervous, quick motioned horse as a tractor for the plow, they likewise began the retreat down the rocky hillsides of their farms and were rapidly followed by the gray birch and the cedar. On the land enriched by the wash from those same hillsides they joined the march of progress towards intensive farming. Today the great-grandson of the oxdriving ancestor superintends his agricultural college, intensive farming on the contracted, rich areas from the tonneau of an automobile. Will his great-grandson superintend similar operations from a flying machine as once more he

climbs the ancient slopes, devastating these new virgin forests in response to a nation's demand for food? Since this paper is largely a peep into the future and not a "Looking backward" by a disciple of Edward Bellamy, the writer leaves the question to be answered in the experience of the economist of a later generation.

When these abandoned plots were adjacent to seed trees, pines in time usually superseded the birches and cedars. In some mixed hardwoods became predominant.

We have, then, in southern New England two different classes of forested areas; the sprout growth from the original, virgin forests which is, of course, by far the larger and more important one, and the new virgin forests of the abandoned farms.

For the purpose of preserving purity many water works companies have acquired large blocks of land contiguous to their supplies. This policy has been particularly favored in Connecticut by very liberal taxation laws with reference to such holdings.

With becoming thrift many of the companies would like to turn this land to account. As a rule the areas which are not already forested are poor in soil and of a character fit only for growing trees. But reforestation and subsequent care cost money and are immediately resolved into a business proposition.

What benefit or benefits may be expected from operations of this kind?

The writer is aware of the theories advanced by the water works men of a former generation, and to a certain extent by those of this one, regarding the value of forested areas in conserving a water supply by influence on evaporation, melting of snow and runoff. With all possible charity towards his colaborers in the water works vineyard he confesses, nevertheless, to a good deal of skepticism on this point. Excepting under certain not very common conditions, it seems unlikely to him that the average forested area will conserve a water supply any more effectually than it would unforested. The great benefit, therefore, must come directly from forest products.

Can an area be reforested, cared for during the long term of years which must elapse before it yields a return, and be made to pay? Viewed in the light of present knowledge of the subject, the answer is unquestionably "yes."

The forester of the Hartford Water Department, after careful study and analysis of the subject, has estimated that an area reforested with white pine should net 4 per cent compound interest on the investment at the end of fifty years. This calculation is based on a

cost of $7 per acre for planting and a land value of $12 per acre, proper allowances being made for care and taxes.

At a meeting of the New England Water Works Association about two years ago a practical lumberman of twenty-five years' experience stated that on 43 acres of mixed forest forty-five years old he had netted 19 per cent annually on the original investment after charging off yearly 6 per cent on account of it. The bare land had been purchased by his father as an investment forty-five years before. This was a natural forest, having been uncared for during the whole period of growth. In this case the goose which laid the golden egg was killed for the whole forest was cut. Practical forestry presupposes a different course.

Since the methods of reforestation practiced on the Hartford Water Works appear to be typical of those in vogue throughout this region it may be well to cite some of their salient points.

Single furrows are plowed 5 feet apart and in these the trees are planted 6 feet apart. The department has its own nursery thus being able to plant seedlings more cheaply and in better condition than would be the case were they purchased from nurserymen.

Planting chestnuts and hickory nuts in the open field has been attempted but the squirrels found them and wrought such havoc that the practice was discontinued.

White pine has been a favorite for planting, both because of its rapid growth and of its value for lumber.

Within the past three or four years a disease, probably the cottony scale, has attacked the pines and injured a large percentage of the new shoots. Whether anything more serious than a temporary setback to the growth of the tree will result, time must determine.

Reforestation and forestry operations in general are productive of certain benefits which may be termed incidental.

Water works superintendents, particularly those in charge of our larger plants, know the difficulty of retaining economically many of their more valuable laborers during certain seasons. In New England this is especially the case in the winter. Such men, if discharged are able usually to secure work elsewhere and their loss is apt to cripple the service when they are most needed. The scientific operation of a large forest would furnish work during the slack season and offers a solution of the problem.

Another incidental benefit, not to the water department but to the public at large, one which it would be difficult to measure in dollars and cents, is the value of such areas as parks.

One of the oldest and most competent water works superintendents in Connecticut, in conversation with the writer not long since, offered this feature as a prime objection to forestry operations on the sheds of public water supplies. His argument was that instead of constructing drives and inviting the public to use them, all people should be kept away from the water sheds as much as possible. This is not an uncommon opinion but in it the writer does not concur. When one compares the efficient and dignified manner with which a New York traffic officer directs the vast streams of vehicles and pedestrians, with the agitated efforts of a similar officer in one of our smaller cities where the custom has just come in vogue, the result is often ludicrous. In the former case it has been so long practiced as to be thoroughly understood and appreciated by the traveling public. The proper use of any park, similarly, is a matter of public education. The extensive drives in the reservoir parks of the Hartford Water Works have been in use, with proper restrictions, for years and very little trouble from abuse of the privilege has been experienced.

The arch enemy of our forests is fire. To guard against this, on any forested area of considerable size, a patrolling system should be established. This at once opens the whole broad subject expressed in the last half of our theme, "The general care of water sheds." As a general proposition the patrolling force which is necessary to enforce the laws relative to pollution can likewise keep watch over the forests.

The patrol of the Hartford water sheds is particularly well organized and equipped. Each man has a beat assigned him and is provided with a watchman's clock, of a type especially adapted to this service. All of them hold commissions as special policemen from the governor of the state, and culprits, in whatever town they are apprehended, are under the jurisdiction of the police court of Hartford.

In closing it may be said that on account of the recent advent of improved methods of purifying and sterilizing water and an increasing public demand for their practice, the wholesale purchases of water shed lands seem likely to decrease. In the natural course of events, however, there will be on almost every water shed some land owned by the water department which may be turned into a source of income through reforestation. No use to which it might be put with profit could be less objectionable than that of growing trees. If any further argument in support of the practice were necessary it would seem to be supplied by the greatly increasing numbers of water departments which are adopting it.

DISCUSSION

Mr. John M. Diven: The city of Troy had several hundred acres of land which it was renting and getting little from. We planted 200 acres of this land with trees, 1200 trees per acre, at a cost of $11.14 per acre.

Mr. B. C. Little: The writer of the paper says that there is no benefit to be derived from the conserving of the water by reforesting, and says the only great benefit must come directly from the forest property. But there is a benefit to be derived from planting a water shed that is in close proximity to the shores of the lake, in preventing, after sudden heavy rains, the washing of dirt, sticks, leaves, etc., into the lake. If you have a pine forest, the pine forest also prevents a great accumulation of leaves, etc., which is a decided advantage. We have done quite a good deal of foresting in Rochester, buying our trees from the State Forest Commission at a merely nominal price, and the members of this commission have given us a great deal of aid in the way of advice, at times coming to supervise our planting to see that it is done properly and to watch the progress of the trees at intervals of four or five years.

Mr. John M. Diven: We planted at Troy six and a half miles of Norway Spruce along the bank of the reservoir, and expect to obtain a great deal of protection in the way of preventing leaves and rubbish from blowing into the reservoir, as well as rubbish being washed in.

WORK DONE FOR THE PREVENTION OF WATER WASTE IN THE CITY OF NEW YORK AND RESULTS ACCOMPLISHED THEREBY

By I. M. de Varona

In order to avert the threatening danger of a serious shortage of supply for Manhattan and The Bronx in 1912, and, later, to avoid if possible, the large expense attending the development of additional sources of supply for Brooklyn, which would otherwise have been required to adequately provide for the consumption in that Borough until the Catskill water was available, the Department of Water Supply, Gas & Electricity instituted a vigorous campaign to reduce waste. The intended purpose was fully and most satisfactorily accomplished in both cases. The crisis of 1912, in Manhattan and The Bronx, was tided over, and Brooklyn may now safely await the introduction of the Catskill supply without further developing its watershed.

The estimated daily reduction in consumption in Manhattan and The Bronx reached a maximum of 71 million gallons in August, 1911, averaged 65 million gallons for the last 6 months of 1911 and almost 50 million gallons for the year 1912, while the total reduction since the beginning of the work in the fall of 1910 to April 1, 1913, aggregated over 39,700 million gallons. In Brooklyn the maximum reduction of 34 million gallons daily was effected in February, 1913, and the average daily reduction since August, 1912, the commencement of the house to house inspection, to April 1, 1913, amounted to 25 million gallons, while the total saving since the beginning of the pitometer work in July, 1910, to April 1, 1913, aggregated over 9000 million gallons. This reduction in consumption in the Borough of Brooklyn was such that the average daily consumption for the month of January, 1913, would give a per capita consumption of only 73 gallons, which is the lowest per capita consumption for any January since 1894, or for the last 19 years.

The aggregate value of the water thus saved, if figured at meter rates ($133 per million gallons) would be nearly $6,500,000 and the total cost of the work done to effect this saving was about $167,000, which would be reduced to $131,000 if the amount for fines imposed (i. e., $36,000) were deducted.

Owing to the unprecedented magnitude and importance of these results, a statement of the methods employed to secure them, may be of interest.

CONSUMPTION AND WASTE

The water supply of a community should provide for domestic, commercial, sanitary and ornamental purposes, as well as for fire protection, so that if the total consumption did not exceed the quantity of water required for these various uses, there would be no waste. This condition, however, never obtains in practice, nor can we closely determine the proper per capita amount of water for the different purposes above mentioned. It will vary considerably with the locality, season, industrial development and wealth and mode of life of the people. Thus, the per capita consumption is much less in European cities than in our own, even if the larger waste here be taken into account. The Royal Commission appointed to report on the new water supply for London, found that 35 Imperial gallons, or about 42 United States gallons, was an ample quantity for all purposes, but this consumption is considerably less than that of our American communities, among which wide variations are found, of which the following are a few examples:

	ESTIMATED POPULATION 1912	DAILY WATER CONSUMPTION PER CAPITA 1912
New York City, N. Y.	5,053,000	100
Chicago, Ill.	2,350,000	199
Philadelphia, Pa.	1,600,000	200
St. Louis, Mo.	710,000	118
Boston, Mass.	718,900	125
Cleveland, O.	660,000	111
Baltimore, Md.	569,000	128
Pittsburg, Pa.	517,000	236
Detroit, Mich.	566,383	185
Buffalo, N. Y.	450,000	310
San Francisco, Cal.	450,000	87
Milwaukee, Wis.	420,000	113
Cincinnati, O.	402,000	131
New Orleans, La.	275,000	64
Minneapolis, Minn.	323,476	73
Kansas City, Mo.	260,000	108
Providence, R. I.	260,000	68

Even in the same city differences in the per capita consumption is to be expected. In New York it will naturally be found higher in the wealthy residential districts of Fifth Avenue or Riverside Drive than in the poor East side tenement sections.

The per capita consumption for New York City for 1910 (111 gallons) was lower than that of the next 5 largest cities in the United States, i. e., Chicago, Philadelphia, St. Louis, Boston and Cleveland, for the year 1912; and this in spite of the fact that in New York a floating population of many thousands, not included in the census, is housed, and that there are an equally large number who live outside of the limits of New York City, but who work in the city, also left out of the census. If this transient population were considered, the per capita consumption in New York would be materially reduced.

Compared with other American cities, New York, therefore, is economical in the use of water, even if we include our waste.

The city is divided into 5 Boroughs—Manhattan, The Bronx, Brooklyn, Queens and Richmond. The work for the reduction of waste, to be discussed, was done in Manhattan and The Bronx and Brooklyn.

SUPPLY OF MANHATTAN AND THE BRONX

These 2 boroughs are supplied from the Croton, Bronx and Byram Rivers. The Croton, which is the main source, draws from a watershed of 360 square miles and furnishes all but about 18 million gallons daily of the entire supply. There are in its watershed 9 storage reservoirs, with an aggregate capacity of over 104,000 million gallons. The Bronx and Byram Rivers drain a watershed of some 22 square miles, in which there are 4 reservoirs and ponds, with a total capacity of somewhat over 6000 million gallons.

During the first half of 1910, the rainfall filled all the reservoirs and 11,000 million gallons were wasted from the new Croton Lake, our main collecting reservoir. From June, 1910, however, to the latter part of August, 1911, the rainfall was less than recorded for any similar period during the past forty-three years, so that with a resultant extreme low flow in the Croton valley, the evaporation from the surface of the reservoirs and lakes at times exceeded the flow of the river. The large amount of storage enabled us, however, to furnish an ample supply in 1910, in spite of the drought; but at the beginning of 1911 the storage on the Croton, Bronx and Byram watersheds was only 40,589 million gallons, or less than 40 per cent

of the total capacity of the reservoirs, and more than 5000 million gallons less than the amount of storage at the beginning of 1910. Even under these conditions there was no reason to anticipate a shortage in 1911, provided we had a normal rainfall, with the resultant runoff; but, in January and February, 1911, the rainfall was below the average and in view of the dry condition of the soil, unfavorable to the collection of as large a percentage as usual of the winter and early spring rainfall it was evident that the storage would be so depleted as to probably result in an inadequate supply in 1912.

In 1910 the average daily consumption was 331 million gallons, or 120 gallons per capita based on the population given in the 1910 census. On this basis, assuming an increase of 3 per cent annually due to increase in population, the average daily consumption would be about 341 million gallons in 1911, and about 352 million gallons in 1912. From the total available storage capacity of the 3 watersheds, it is estimated that 323 m. g. d., could be drawn, leaving a reasonably safe amount in storage, provided there were no greater period of drought than has been experienced since 1868.

In view of the increase in consumption (see Table No. 1) and the small amount in storage due to the conditions already stated, it was very evident that some action would have to be taken promptly to reduce the average daily consumption and to secure an emergency supply in case of necessity. Our citizens were informed, through the press, of the existing conditions, work was started actively for the reduction of waste, and the preparation of plans begun to secure an additional temporary supply from the Ten Mile River.

PREVENTABLE WASTE

For the purpose of this report, "Waste" shall be considered as the quantity of water drawn in excess of that required for the uses already specified, and will be designated as "Preventable" when the value of water wasted is greater than the cost of the methods required to save it, whence it follows that it would be considered non preventable when the reverse conditions obtain, so that "it will not pay" to save the water, these designations being based exclusively on practical and economical considerations. For "value" must be understood not simply the normal money cost or selling price of the water, but also the increase or decrease due to the condition of the supply at the time.

PROBABLE PERMANENT REDUCTION OF WASTE

Were the use of water strictly confined to the purposes already enumerated, most of our large cities would probably save, perhaps, 50 per cent or more from their actual consumption. As a general proposition, however, the absolute elimination of waste seems unattainable within practical limits of cost, and without, in many cases, causing much inconvenience to consumers. The author has held before that under existing conditions in our city, it would not be advisable in making a safe estimate, to assume a larger *permanent* saving in consumption from the work to prevent waste, than from 15 to 20 per cent, and the results recently obtained seem to bear out these figures.

SOURCES OF WASTE

These may thus be enumerated:

1. Maladministration in the use of water for public and commercial purposes and careless management within the buildings, especially during periods of extreme temperature, when the faucets are allowed to run full in order to draw the water hot or cold, as required. To this may be added the more than ordinary liberal use of water due to habits, etc., by wealthy residents.
2. Water wasted through leaky fixtures within the buildings, especially from toilet tanks, and from roof tanks and other service pipes and appurtenances outside of the buildings.
3. Water wasted by leaks in the streets from distribution mains, valves, hydrants, etc.

The work done by our department shows that by far the larger portion of the preventable waste is due to causes No. 1 and 2, the leakage through the street mains being relatively small. It follows that the consumers are responsible for the larger part of the waste and that it may, therefore, continue, if public attention is not called to this fact, or if the value of the water to be saved, according to the normal schedule of charges, is less than the cost of the method to be adopted to check the waste. The importance of calling the attention of consumers to the waste resulting from their neglect to properly supervise fixtures, service pipes, handling of faucets, etc., is therefore apparent, and the beneficial effects to be obtained therefrom have been exemplified once more during our recent work.

METHODS FOR REDUCING WASTE

The following methods are generally employed, i.e.,

1. Calling to the attention of consumers the need of checking waste, either for economical considerations or to prevent a threatened shortage on account of inadequate supply, or for both reasons.

2. House to house inspection to detect and repair leaks.

3. Examination for leaks outside of the buildings, in service pipes as well as distribution mains and appurtenances, to locate and repair underground leaks.

4. Metering of all connections where the cost and existing conditions of the supply warrant this measure.

The latter method (No. 4) cannot, at present, be generally applied in our city, nor was it available for the work under consideration. Under the existing legislation, the Water Department can compel the installation of meters by property owners only in buildings where water is used for commercial purposes, so that out of a total of 365,000 services, only 86,000 or less than one fourth, are metered, and of this number 60 per cent are in the Borough of Manhattan. In this connection, it seems pertinent to add that a general and strong opposition on the part of property owners has hitherto been shown whenever a system of general metering, or even the adoption of preliminary measures to properly plan its installation, have been proposed, so that, in view of the large increase in the water supply to be expected from the Catskill sources about the beginning of 1916, it were inopportune, if not useless, to agitate this question at present. Probably more than a decade will elapse before the first installment (250 m. g. d.) of the Catskill supply will be fully required for the consumption, and until additional works for further increase of the supply are necessary, the value of the water saved by metering would probably be less than the annual charge due to installation of meters. It should furthermore be borne in mind that in wealthy residential districts, the introduction of meters will probably increase the revenue materially, but not diminish the consumption, and that the efficient limit of metering in our city will be reached before meters are placed in every service.

We had, therefore, to confine ourselves to the first, second and third methods above enumerated, i. e.

PUBLIC AND INDIVIDUAL NOTICES

Public attention was repeatedly called, through the press, to the inadequate supply available in those boroughs in which existing conditions warranted such a statement, the requisite data being also given in support thereof and the imperative need shown of preventing waste in order to avoid a threatened shortage; while the following notice printed in English, Italian and Yiddish, was delivered at all premises requiring consumers to stop all leaks in their fixtures, advising them at the same time that the department would impose a fine if after the first inspection, leaky fixtures were not promptly repaired:

IMPORTANT

To the Owner of the Premises:

To stop waste of water, an inspection is to be made of these premises, and your attention is called to the necessity of having all fixtures in good order, as the rules of the Department provide a penalty of two dollars ($2.00) for each leaky fixture. The fixtures which are ordinarily found out of order are tanks of toilets, faucets and ball cocks controlling overflow of tanks.

You are hereby notified to have all leaky fixtures immediately repaired.

The use of hose, either inside or outside of buildings, is prohibited.

It is hoped that you will do everything in your power to stop all unnecessary use of water so that we may avert as much as possible a situation which would be most serious.

These notices, forwarded about the middle of June, 1911, in Manhattan and The Bronx, met with instant and efficient response from our citizens, so that a large reduction in consumption resulted almost immediately. The house to house inspection commenced about the same time. The weekly consumption during June was as follows:

WEEK ENDING	CONSUMPTION (M.G.D.) 1911	1910
June 3d	287	
June 10th	290	
June 17th	279	
June 24th	272	320 (June)
July 1st	264	342 (July)

It is interesting to note that while only about 14 per cent of the total number of premises were inspected during the month of June, such a large reduction in average daily consumption was effected.

It is evident that the latter was principally due to the notices which were delivered to the various premises.

HOUSE TO HOUSE INSPECTIONS

The larger portion of waste in the city of New York is due to defective fixtures within the buildings, and especially to the water lost from roof and toilet tanks, and leaks from the latter are also the most difficult to detect, as the escape of water is not always apparent to the eye, although the noise made is sufficient, as a rule, to enable the occupant of the premises to detect the leak.

Next to leakage of tanks is that from faucets, due either to their being carelessly left open or to need of repairs usually resulting from wearing out of washers.

The Board of Estimate and Apportionment having approved the issue of $100,000 revenue bonds to pay for a house to house inspection, a force of about 100 inspectors were placed in the field in June, with the necessary clerical force to handle the inspection reports, notices of leakage, etc., this force operating under the direction of the Water Registrar. The method of inspection is detailed in the Appendix. The Engineers Bureau determined the amount of water consumed before and after house to house inspection, and for this purpose 18 districts were laid out in the Borough of Manhattan, as shown on Plate 1. The flow into these districts was determined by pitometer measurements, and a record of the reduction in leakage resulting from the inspection was thus obtained; the results are given in Table No. 3. The house to house inspection was continued with full force until September, when the reduction in consumption, together with the increased rainfall, made it unnecessary to prosecute the work as vigorously as in the early part of the summer. At least 2 inspections were made in each building where leaks were found, and as these were shown in nearly all buildings examined, the number of inspections was practically double the number of buildings given in Table No. 2.

The results of the work done are shown by the following table of consumption, in which the reduction has been approximately apportioned between the work done in stopping leaks in mains, and the work done in stopping leaks and waste in buildings:

Consumption in Manhattan and Bronx (M.G.D.)		Estimated Consumption Assuming Increase of 3 Per Cent Equivalent to Rate of Increase in Population	Estimated Reduction in Consumption		
			By stopping underground leaks[1]	By reducing leakage and waste in buildings	
Month	*1910*	*1911*	*1911*		*Total*
Jan.,	335	334	345	4	7	11
Feb.,	336	331	346	4	11	15
Mar.,	327	327	337	6	4	10
Apr.,	326	320	336	6	10	16
May,	326	310	336	8	18	26
June,	329	286	339	9	44	53
July,	342	287	352	9	56	65
Aug.,	336	275	346	9	62	71
Sept.,	335	277	345	10	58	68
Oct.,	332	278	342	11	53	64
Nov.,	321	271	331	11	49	60
Dec.,	333	283	343	11	49	60

[1] The column headed "By stopping underground leaks" refers to leaks discovered by the pitometer and does not include a large number of leaks, some of considerable amount, which were located and repaired by the regular maintenance force. The amount of these leaks would reduce by an equal amount the quantities reported under the heading "Leakage and waste in buildings."

The above figures show a large reduction in consumption secured at a small cost (see Table No. 4). They prove the value of the results to be obtained if we could economically eliminate all waste.

With the storage now available, there was no need or economy in continuing the work for waste prevention, and it is improbable that it may be advisable to resume it before the Catskill water is introduced. A sufficient force should, however, be retained for house to house inspection, so that all buildings may be inspected at intervals say not greater than two years, thus preventing a return to the conditions that existed before the special work was undertaken. A gradual increase in consumption is probable, due to the increased use of water when no danger of shortage in the supply is apprehended, and it is not reasonable, therefore, to expect that the full reduction made in 1911 will continue in subsequent years, although the records for 1912 and 1913, to date, show a large reduction in the consumption as compared with the estimated consumption based on 1910. (See Table No. 1, Diagram 2.)

Owing to lack of interest on the part of owners of property and their tenants, many of the leaks in fixtures that are repaired as a result of the house to house inspection, reappear within a few months after such inspection. The opening of faucets during cold

weather to prevent freezing of water in pipes causes a large waste amounting at times to many million gallons daily, the greater part of which is unnecessary, as a small stream from the faucet will accomplish the result as well as a full stream. If owners and tenants would exercise ordinary care in avoiding waste of water supplied to them by the city, but for which they must eventually pay the cost, either in water bills, or, when the water revenue is insufficient, by direct taxes, there would be a reduction in the yearly expense for the maintenance of the supply and in the amount necessary for the construction of new works as well as in the interest charges for bonds that have to be issued to cover the cost of such works.

Under the ordinances of the city of New York, the following provisions are made covering the maintenance of fixtures in good repair, the penalty in case of violations and the conditions under which hose may be used:

Rule 3: All persons taking water, shall keep their service pipes, stop-cocks, ball-cocks, fixtures, meters, and apparatus in good repair and protected from frost at their own expense, and shall prevent all waste of water.

For violation of this rule, a penalty of $2 is fixed in addition to those specified in Rule 48.

Rule 7: The use of hose inside buildings for any purpose whatever is allowed only where the premises are fully metered.

Rule 9: The use of hose outside of buildings is not permitted except where the premises are fully metered and a special permit obtained from this Department.

Permits will be issued yearly free of charge upon application for the use of hose for sprinkling or washing of sidewalks, stoops, areas, house fronts, yards, courtyards or gardens.

Permits must be shown on request of Police or Inspectors of this Department.

Hose to be used under these permits must be watertight and provided with a stop-cock at the nozzle.

For violation of this rule a penalty of $5 is fixed in addition to those specified in Rule 48.

Rule 48: In case of violation of any of the preceding rules, requirements and regulations, or any of the Laws or Ordinances relating to water supply, or if it shall be found that a meter has been tampered with, the water supply will be shut off and any advance payments forfeited, unless such additional charges as the Commissioner may impose are paid promptly. Nor will the supply be re-established except upon payment of the expense of shutting off and turning on, and satisfactory assurance that no future cause for complaint shall be given.

EXAMINATION OF LEAKS OUTSIDE OF BUILDINGS, IN SERVICE PIPES AND MAINS, AS WELL AS VALVES, HYDRANTS, ETC.

Due attention was given to the measurement of flow in pipes and mains outside of buildings, to locate and stop leaks. As investigations made in 1910 had shown some large leaks, especially in mains laid under the East River, and as there was great likelihood of leaks along the river that discharged into it and therefore did not show on the surface, careful measurements were made of the flow of water in various parts of the city to locate these underground leaks, particular attention being given to the river front, and a special division for this class of work was formed, to which were assigned men who had experienced in similar work in this and other cities. For details see Appendix and Table No. 5. Broken mains were also found where the loss of water was very great. In one instance, where the broken main lay at the bottom of the East River, the loss amounted to over 3 million gallons per day.

The underground leakage stopped was about 10 m.g.d., which, if valued at meter rates would amount in a year to nearly $500,000 while the cost of this work, covering a period of about two years was $19,000, or say $9500 per year.

TEMPORARY SUPPLY FROM THE TEN MILE RIVER

When shortage in the supply seemed possible, surveys were made and plans, contracts and specifications were prepared to secure a temporary daily supply of about 50 million gallons from the Ten Mile River, a tributary of the Housatonic, which was the most available source. The Ten Mile River flows into the state of Connecticut at a point about six miles north of Pawling, the most northerly point on the Croton watershed. It has a watershed of about 200 square miles above Webatuck, where it was proposed to erect a pumping station that would deliver a supply through a pipe line into a tributary of the Croton River, just south of Pawling. This pumping station would have a capacity of about 100 m.g.d., and the steel pipe would be 60 inches in diameter and about 8 miles long. The water would be taken from the river during the late fall, winter and early spring months, when the flow of the Housatonic would be greater than that required to meet the demands of riparian owners below the point where the Ten Mile River discharges into the Housatonic. By taking the waters only when

they were not required for other purposes, the question of interstate rights would be practically eliminated, as it was considered doubtful whether any Federal Court would enjoin the city from taking water when the riparian owners could not show that they were damaged thereby. The works to be constructed were of a temporary character, to be used during the four or five years that might elapse before the Catskill supply was available. When this project was recommended, the writer appreciated and called attention to the fact that it would probably be unnecessary ever to draw water from the Ten Mile River, but the damage to the city of New York, resulting from a shortage of water, would be so great that no efforts to prevent such a disaster should be spared[1].

It was estimated that the minimum time required to construct the pipe line would be four months from the date of giving the order, and that at least four months would be needed to build and equip the station so as to put it in service.

Meanwhile, the rainfall and the resulting runoff, improved the

[1]The following is an outline of the plan proposed:

1st. A pumping station on the west bank of the Ten Mile River just above the cross roads at Webatuck. . . .

2d. A low dam, probably not over three feet in height, across the river to form a small forebay, with an intake channel leading to the pumping station, which would be located on meadow land, immediately adjacent to the river. The pumping station would consist of a plant having a nominal capacity of 100 million gallons daily, using steam for power, it being assumed that this plant would be operated for not over six months in the year.

3d. A single 5 foot steel pipe line into which the pumped water will be delivered, to be laid, in general, along the line of the New York Central R. R. from Wingdale to the Paterson Swamp at a point south of Pawling. This pipe will be about 45,000 feet in length and will be laid either on the railroad right of way or through private property adjoining same.

4th. *Cost:* The approximate estimate of cost, necessarily subject to material modification as detail plans were developed, was as follows, exclusive of possible claims from riparian owners,

Pumping Plant, including dam, intake and buildings	$450,000
Pipe line, including land damages	550,000
Total	$1,000,000
20 per cent to be added for contingencies	200,000
Total	$1,200,000

5th. *Reservoirs:* No provision was made for storage reservoirs as by pumping a comparatively large amount during 6 months of the year, ample storage would be available in the Croton watershed for the Ten Mile River water.

conditions so that in October we felt justified in abandoning the Ten Mile River project.

The comparatively heavy rainfall in the latter part of the winter of 1911–1912, was sufficient to fill all the reservoirs, so that there is no reason to anticipate any shortage for Manhattan and The Bronx, prior to the introduction of the Catskill water, provided ordinary care is exercised by citizens to prevent leakage. The investigations of leakage outside of buildings and inspection within buildings, and the investigation and repair of leaks in the distribution system, which can be made by our regular force, are the only ones at present carried on and which will be continued. The special house to house inspection was discontinued as needless.

RESULTS OBTAINED

The average daily consumption of Manhattan and The Bronx (see Table No. 1) was 331 million gallons in 1910, giving a per capita consumption of 120 gallons. On the basis of the consumption figures for 1910, assuming an increase of 3 per cent annually due to increase in population, the average daily consumption would increase to 341 million gallons in 1911 and to 352 million gallons in 1912. By the work to check waste, however, the average consumption for the year 1911 was reduced to 298 m.g.d., or 105 gallons per capita, but the actual reduction was really greater than shown by the above average, as the effect of the water waste work did not show great results until July, 1911, when the reduction reached 65 million gallons daily and was thus maintained on average up to January 1, 1912.

While there was a natural increase in the consumption for the year 1912, the average daily consumption was only 303 million gallons, corresponding to a per capita consumption of 104 gallons. The consumption for the month of December, 1912, averaged 297 million gallons daily which is less than the average daily consumption for the year 1904. This estimated reduction in the average daily consumption due to the water waste work is clearly shown in Diagram No. 2 which illustrates the natural increase in consumption since 1902, and shows that at the present time, the average daily consumption is the same as that for 1904. On the basis of the estimated consumption for 1911, 1912, and 1913 some 39,000 million gallons have been saved, which if valued at meter rates, $133 per million gallons, would amount to about $5,187,000, at a cost to the city of

about $100,000, exclusive of the fines imposed for leaky fixtures during the time of house to house inspection. (See Table 2.) The per capita consumption has been reduced from 120 gallons, which was the average for these two boroughs in 1910, to 101 gallons, (see Diagram 3 and Table No. 6) which is the per capita consumption for the first quarter of 1913. Diagram No. 3 shows that the per capita consumption is the same as that for the year 1895.

METERS

It has already been stated that the general installation of meters was not allowed under the existing legislation. A brief reference to previous discussions of this subject and measures proposed in regard thereto seems, however, pertinent.

The advisability of the general installation of meters—nay, its need, in order to secure proper economic management of the water supply, reduce preventable waste and equitably regulate charges for water, has been so often demonstrated, and is today so generally recognized, that further exposition of proofs in support thereof seem superfluous. Among hydraulic engineers and managers of all water works, both in this country and in Europe, there is not a dissenting voice on this proposition. By the general public, however, it has been received throughout this country with disfavor, and in our city with a specially marked and persistent opposition sufficient hitherto to prevent the adoption of even the preliminary measures necessary to prepare a plan for installation. Personal considerations in some cases, prejudice or motives which need not be here considered in others, have no doubt contributed to this opposition, but valid reasons therefor, and probably the main ones, are to be found in our present regulations for the installation of meters, which prescribe that the cost and installation of the meter shall be paid by the house owner; that the latter shall also bear the expense of all necessary repairs, and that metered water shall be paid for at the rate of $133 per million gallons. To compel the house owner to buy the meter and keep it in repair at his own expense, is not only onerous, but also against the usual practice in similar cases and therefore unequitable, while the charge of $133 per million gallons is extortionate, as compared with the general or flat charges for unmetered water, and its enforcement ill advised policy on the part of the city, which thus discourages and discriminates against the adoption of the very measure it is endeavoring to generalize.

The author, while discussing this subject in 1902, in connection with the Brooklyn water supply, reported that available data then showed that the difference in charge per million gallons between the unmetered and metered water was about $46; that the charges for metered water per million gallons were about $43 more than the cost per million gallons of all salable water based on total expenditures; and that the receipts per million gallons for unmetered water were, on the contrary, about $2 below the actual cost per million gallons of salable water based on total expenditures; in other words, that the metered water was sold with an approximate profit of 50 per cent on total cost, while on unmetered water the city lost above $2\frac{1}{2}$ per cent. In this same report plans were discussed to so regulate the charges as to either obtain simply sufficient revenue to cover the total expenditures, leaving little or no surplus, or to secure the present average receipt per million gallons of water consumed, with the surplus of profit then shown, on a more equitable basis.

Under these conditions, the writer had recommended and the department had held, in regard to this matter:

First: That the water supply of the city should be metered.

Second: That the meters should be purchased and installed by the city at its sole expense, and not by the owners as at present.

Third: That the city should also make, at its sole expense, all necessary repairs to meters.

Fourth: That the period of installation should be spread over, say, four or five years, so as to distribute both the expense and tearing up of streets and sidewalks.

Fifth: That the meter rates should be so established as to prevent the curtailment by penurious house owners of the amount of water necessary for all domestic and sanitary purposes. A minimum flat rate should therefore be established based on the amount of water per capita required for the above purposes, and the corresponding total amount would be charged for the building, whether or not it was used. For the excess over that prescribed amount the rates would be higher.

Sixth: That, as an indispensable preliminary measure the necessary data should be obtained for the proper establishment of meter rates. For this purpose the mode of procedure would be as follows:

(*a*). Authorization should be obtained from the Legislature to enable the commissioner to install and put into service meters in all such districts and sections as would in his opinion furnish the best

opportunities for securing complete and accurate information as to the consumption and waste of water.

(*b*). After the installation of these meters in the various districts selected, careful readings would be taken for a certain time, particular attention being given to the condition of the fixtures and leakage therefrom, etc., which would be duly recorded, after which a rigid inspection would be made to locate and stop all leaks in fixtures and insure their proper condition and the reading of meters continued. The difference found between the amount of water drawn with leaky fixtures as originally in service and the amount used after the fixtures were put in proper order, would represent the waste. This experimental work in the various districts metered should be continued regularly for, say from 6 months to one year, tenants and householders being cautioned to use water freely through the whole period, as they had always used it before.

With the above data duly recorded and copies of the water bills paid by the consumers, the necessary information would be available to intelligently establish the proper meter rates and ascertain the probable results on the installation of these meters.

The attitude of the department in regard to this matter, as outlined above, was known to and met with the endorsement of the Merchants Association of New York, who, in support thereof, secured the passage of what is known as the "Stanley Act" (Chapter 611 of the Laws of 1906). Under its terms the Commissioner of this Department, when authorized by the Board of Estimate and Apportionment, was to proceed immediately to install meters in various districts to be selected by him for the purpose specified and detailed above, Paragraph 6, Sections *a* and *b*. The Act directed that the Commissioner of the Department should report to the Board of Estimate and Apportionment on the necessary measures to carry the said act into effect, and appropriation to be made for its execution. This requirement was complied with and a full report submitted to the Board of Estimate and Apportionment, as part of which 9 typical districts were selected for the installation of meters in Manhattan and The Bronx, as follows:

1. Typical Italian tenements, low service.
2. Good class private houses and medium class apartment houses, tower high service.
3. Medium class apartment houses and private houses, reservoir high service.
4. Typical Hebrew tenements, new buildings, low service.

11
9
7A
12
7
3A
13
3
14
4
1A
1
5
15
8
16
17
6
18
5
19
2
20
BRONX
QUEENS
BROOKLYN
CENTRAL PARK
10
11
9
CITY OF NEW YORK
DEP'T OF WATER SUPPLY, GAS & ELECT.
BOROUGH OF MANHATTAN
MAP
SHOWING AREA COVERED BY
WATER WASTE INVESTIGATION
1913
2400 1200 0 1200 2400
Chief Engineer

Diagram No. 1.

CITY OF NEW YORK

DEPARTMENT OF WATER SUPPLY GAS & ELECTRICITY

BOROUGH OF BROOKLYN

MAP

SHOWING AREA COVERED BY

WATER WASTE INVESTIGATION

1913

J. Mdel Vasvea

CHIEF ENGINEER

Diagram #4

5. Medium class flat and two family houses, low service.

6. Buildings of the same character as No. 5, but in high pressure service.

7. Typical Hebrew tenements, buildings several years old, remodelled.

8. Two and three story frame houses.

9. High class apartment houses.[1]

In Brooklyn seven similar districts were selected.

No further action has been taken to date in regard to the general installation of meters and for the reasons previously given, it is not likely that it will be carried into effect for several years, as it would not prove economical.

SUPPLY OF BOROUGH OF BROOKLYN

The supply for Brooklyn is obtained mainly from the watershed of the south side of Long Island, east of the Borough limits, and extending easterly to Suffolk County, a distance of about 40 miles, and covering an area of 168 square miles. A station located in the watershed on the north side of the island, furnishes, also, about 3 per cent of the supply. The Twenty-ninth Ward and a portion of the Twenty-sixth and Thirtieth Wards are supplied by private water companies, but about 90 per cent of the entire supply is furnished by municipal works. These collect the underground water flowing through the sands and gravels which compose the watershed and the surface water from eight small streams. Twenty-four stations derive their supply from subsurface sources and all the water that is delivered to Brooklyn has to be pumped from one to four times before it reaches the consumer.

As shown by Table 7, the average daily consumption varied materially, the maximum average for any month during 1912 occurring in February and amounting to 159.1 m.g.d. and the minimum in November, amounting to 126.3 m.g.d. The high consumption of February is attributed to the unusually low temperature recorded during that month, while the low consumption of November was due to the effective water waste prevention work carried on during the latter half of the year. It was evident from the consumption in the early part of the year that either additional supply would have to be obtained from the development of the watershed lying east of Rockville Center, or else a material reduction in consumption would

[1] An additional district comprising high class residences was to be added.

have to be effected by the elimination of unnecessary waste. To further develop the watershed would involve the construction of new pumping stations drawing from deep water bearing strata. The recorded draft per square mile of watershed lying east of Rockville Center, has averaged during the past five years, less than 0.6 million gallons, whereas for the watershed lying west of Rockville Center, it has averaged over 0.9 million gallons. As the watershed lying east of Rockville Center has an area of 97 square miles and that lying west has an area of 71 square miles, the increase in supply, if the development on the east watershed were equal to that on the west watershed, would be equivalent to about 30 m.g.d. There would, therefore, be apparently no difficulty in obtaining additional supply from the existing watershed, but owing to the anticipated introduction of the Catskill supply in the early part of 1916, and the probable shutting down of the Long Island System at that time, the useful life of any new development would be very short and its relative cost necessarily high. Assuming that the life of supplies developed in 1913 would be three years, in 1914, two years and in 1915, one year, the estimated cost per million gallons, allowing interest and sinking fund as well as maintenance charges, for the new work required, would be as follows:

YEAR IN WHICH SUPPLY WOULD BE FIRST AVAILABLE	ESTIMATED COST PER MIL. GALS. SUPPLIED
1913	$36.00
1914	42.00
1915	56.00

The experience from the water waste work in the Boroughs of Manhattan and The Bronx during 1911 indicated that for each inspector employed on water waste work a saving amounting to slightly less than one-half million gallons daily was obtained. As the salary of each inspector, together with the necessary clerical force in the office, amounted to about $5 per day, it followed that it would be economical to employ inspectors on water waste work in Brooklyn if the inspector saved only one-seventh million gallons daily, provided such saving eliminated the necessity for extending the water supply system. It was estimated that the cost for maintenance and operation of the system, exclusive of the distribution,

averaged $36 per million gallons, and that by curtailment of waste the cost of maintenance and operation could be reduced to an amount equivalent to $24 per million gallons saved. It would, therefore, be economical to employ water waste inspectors to keep the consumption below the capacity of the existing works, provided each inspector employed saved not less than one fourth m.g.d.

Assuming these premises, the following notice printed in English, Italian and Yiddish, was delivered to all residences:

IMPORTANT

To the Owner of the Premises:

To stop waste of water, an inspection is to be made of these premises, and your attention is called to the necessity of having all fixtures in good order, as the rules of the Department provide a penalty of two dollars ($2) for each leaky fixture. The fixtures which are ordinarily found out of order are tanks and toilets, faucets and ball-cocks controlling overflow of tanks.

You are hereby notified to have all leaky fixtures repaired immediately.

The use of hose, either inside or outside of buildings, is prohibited, unless a permit is obtained from the Department.

It is hoped that you will do everything in your power to stop all unnecessary use of water. Every gallon of water that is supplied to the Borough of Brooklyn has to be pumped twice and some of it three times, so every gallon saved means a saving to the taxpayer.

Use what you need but do not waste it.

These notices were delivered in the latter part of June and the effect was clearly shown in the July consumption, which was 13 m.g.d. less than the estimated consumption for July, based upon the consumption of 1910 and making allowance for an increase of 3 per cent annually for increase in population.

On July 11 the Board of Estimate authorized the appropriation for 40 inspectors and 10 clerks to be employed on water waste work, and these men were appointed early in August.

To determine the effect of house to house inspection, measurements were taken of flow into the various districts before and after the house to house inspection was made and the results of such inspection are given in Table No. 9.

Table No. 8 shows the work done by the force employed on house to house inspection for the prevention of waste of water.

The waste stopped, as shown by the consumption table No. 7, does not include that which was stopped as a result of the house to house inspection notices, which may be estimated as about 10 m.g.d., or about 7 per cent of the entire supply.

The sum of the reduction shown by house to house inspection and that from the water waste notices would equal 25 per cent. This, however, is in excess of the actual reduction in consumption, as some of the waste reappears immediately after the house to house inspection is completed, and gradually increases; and in time the effect of house to house inspection would be practically eliminated.

It is estimated that the actual reduction in consumption due to the water waste work is about 20 per cent, which would represent between 25 and 30 million gallons daily. It is impossible to determine absolutely the exact reduction in consumption due to this work, as there are possible inaccuracies in the measurements of the total amount of water delivered, and weather and other conditions may affect the consumption in different years even in the same month.

Comparison is made between the 1910 rather than the 1911 figures as the water waste work that was being carried on in 1911 in Manhattan and The Bronx together with the notice given through the press of the unusual drought and resultant danger of shortage of supply undoubtedly had a material effect in the curtailment of waste and lowering of consumption figures for the last 6 months of 1911.

The reduction in waste resulted in an average increased pressure of about 3 pounds, and had the pressure been kept the same as before the water waste work was commenced, the reduction in consumption would have been still greater.

It is anticipated that house to house inspection will be continued until the entire borough has been examined, the work done to January 1, 1913, representing about 50 per cent of the premises served by the municipal system. Upon completion of this inspection work, one or more typical districts are to be reinspected, and the reduction in waste from such reinspection carefully determined, so that the relative economy of continuing or stopping house to house work can be decided.

One important result of the reduction in consumption in Brooklyn is the releasing of several million gallons daily for supply for the Borough of Queens, where about 9 m.g.d. are purchased at a price averaging a little over $60 per million gallons.

The per capita consumption in Brooklyn, during 1910, both from municipal and private sources, was 97 gallons, and owing to notices in the public press and to the campaign going on in Manhattan and The Bronx, during 1911, the per capita consumption was reduced to 92 gallons and still further reduced in the year 1912 to 89 gallons.

The average daily consumption, municipal, for January 1913, as shown on Table No. 7 was 122 million gallons. The population supplied was 1,675,000 and with the consumption at 122 million gallons, the per capita consumption for January was reduced to 73 gallons, this being the lowest per capita consumption since 1894. Since August, 1912, when the house to house inspection commenced, it can be estimated that based on the consumption figures for 1910 with a 3 per cent increase due to increase in population, a saving of 6075 million gallons was effected, which if valued at meter rates, $133 per million gallons, would amount to $808,000, at a cost to the city of only $30,400, exclusive of the fines imposed which up to December 31, 1912, amounted to $4400. (See Table No. 8.)

CONCLUSIONS

Through the large reduction in waste effected in Brooklyn, it will be possible to meet all the demands of consumers in that Borough up to the time of the introduction of the Catskill supply, without the construction of additional works, and also to furnish several million gallons daily for the supply of Queens, where water is now purchased from private companies.

In Manhattan and The Bronx the per capita consumption has been reduced to 100 gallons, which is lower than the average per capita consumption of every city in this country having a population of half a million or more.

The estimated value of the water saved in Manhattan and The Bronx has been given, but this value was much greater and, in fact, not easily computed if we bear in mind that every gallon of water saved during that critical period helped to avert the impending shortage and tide us over until the fall rains replenished our depleted reservoirs.

APPENDIX

HOUSE TO HOUSE INSPECTION—BOROUGHS OF MANHATTAN AND THE BRONX

A force of about 150 special inspectors was appointed for this work, and during the month of June the house to house inspection was started.

These new inspectors were divided in squads of 15 or 20, each of which was in charge of 2 of the regular inspectors, and the districts laid out by the Engineering Bureau were taken, block by block, every house being visited.

It was found that each inspector could examine 10 buildings per day, and the work was so arranged that the men in a squad would finish their assignments simultaneously and be ready to shift to another location at the same time. In Manhattan, from June 12 to September 30, 66,223 buildings were examined and wastes were found in 44,055 or about 70 per cent, in which there were 191,483 wasting fixtures. Second and third examinations of these 44,000 and odd buildings required 59,240 visits, so that, all told, there were 125,463 buildings examined in $3\frac{1}{2}$ months in this Borough.

PITOMETER WORK IN CONNECTION WITH HOUSE TO HOUSE INSPECTION

The amount of saving secured by special plumbing inspection was determined by pitometer gaugings of the total consumption before and after inspection. The entire area of Manhattan was divided into 21 sections or districts so selected that they could be isolated from the rest of the system and supplied through a few trunk mains, without seriously disturbing the pressure. The consumption was gauged by pitometer set on these supply mains. The saving shown by these gaugings, excluding office buildings or highly metered sections, amount to 12 per cent of the total consumption.

WATER FRONT

The water fronts of Manhattan and Brooklyn have been practically covered by pitometer waste detection work. A narrow district

including usually 8 or 10 blocks of water front were isolated from the rest of the sytem and supplied by one main through which the actual total consumption and waste was gauged by pitometer for about 48 hours. The metered water was accounted for by special meter readings taken at the beginning and end of the test. Unmetered water, for shipping and boat use, was accounted for as accurately as possible by men stationed to keep record of the boats drawing, the size of the tanks, etc. Domestic consumption was estimated on a per capita or floor area basis. These items of accounted for consumption are totaled and compared with the pitometer gaugings of the total flow into the district. If the discrepancy or unaccounted for water was large enough to indicate waste, a subdivision of the district was made to locate the leakage.

The saving in this work has amounted to 1,400,000 gallons a day in Brooklyn, 4,400,000 in Manhattan exclusive of 5,700,000 gallons a day in river crossing leaks.

During the latter part of the Manhattan work, only the large discrepancies were followed up, owing to the plentiful supply and the then low value of the low service water.

GENERAL WASTE DETECTION

General waste detection work is now being carried on in the higher services as conditions require. The work includes gauging of consumption in small isolated districts within the larger area being investigated, and subsequent night sub-divisions of those districts in which a comparison of the minimum night rate with the 24-hour consumption indicated continuous flow or waste. These districts are generally taken of such size as to be supplied through a 12-inch main without materially reducing pressures. In a district of this size, leakage of importance is usually noticeable in the night rate. On this work the consumption is largely unmetered and the advisability of subdividing a district is determined principally by the ratio of night rates to the average 24-hour consumption and by a consideration of the total supply in connection with the nature of the district. Meter readings or determination of special uses are rarely required.

Table No. 1

Boroughs of Manhattan and The Bronx—Average Daily Consumption, 1903 to March, 1913, Inclusive

Million Gallons

MONTH	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912	1913
January	294	300	314	320	340	325	316	335	334	302	292
February	292	310	320	323	353	340	316	336	331	310	306
March	290	299	319	320	344	329	317	327	327	299	301
April	284	294	315	318	329	325	316	326	320	297	
May	285	296	313	317	323	322	321	326	310	299	
June	283	307	315	328	328	340	330	320	286	308	
July	292	300	323	331	334	342	330	342	287	309	
August	287	301	318	316	330	330	329	336	275	305	
September	291	307	318	332	323	329	335	335	277	309	
October	285	305	321	330	322	321	334	332	278	300	
November	284	302	322	326	314	313	322	321	271	297	
December	290	311	323	337	316	309	314	333	283	297	
Average	287	303	318	325	330	327	325	331	298	303	

Table No. 2

Manhattan—Number of Men Employed, Premises Examined and Leaky Fixtures Found During House to House Inspection, June to December, 1911

MONTHS	NUMBER OF INSPECTORS AVERAGE PER DAY	NUMBER OF CLERKS FOR OFFICE WORK AVERAGE PER DAY	NUMBER OF PREMISES INSPECTED	NUMBER OF LEAKS FOUND	PER CENT PREMISES HAVING LEAKY FIXTURES	NUMBER OF PREMISES RE-EXAMINED	NUMBER OF FINES IMPOSED FOR FAILURE TO REPAIR FIXTURES	AMOUNT OF FINES IMPOSED
1911								
June	87	13	12,834	47,370	75	2,716	303	$606.00
July	105	25	18,644	56,107	69	21,405	4,496	8,992.00
August	114	21	23,893	48,419	60	17,753	2,175	4,358.00
September	77	21	10,852	33,100	70	17,366	2,510	5,020.00
October	35	24	4,109	7,058	48	8,803	1,823	3,646.00
November	18	13	1,621	3,413	47	5,215	299	598.00
December	7	4	418	1,768	56	2,233	245	490.00
			72,371	197,235		75,491	11,855	$23,710.00

Total cost of work to December 31, 1911, $58,158 for Manhattan and the Bronx.

TABLE No. 3

Saving of Water Secured by House to House Inspection in Manhattan, as Indicated by Pitometer Gaugings of Consumption

(Boundaries of districts are shown on the accompanying map)

DISTRICTS	CONSUMPTION BEFORE INSPECTION	CONSUMPTION AFTER INSPECTION	SAVING
1	8,284,000 gallons	6,600,000 gallons	1,684,000 gallons
2	11,444,000 gallons	10,613,000 gallons	831,000 gallons
3	14,823,000 gallons	12,710,000 gallons	2,113,000 gallons
4	12,737,000 gallons	11,410,000 gallons	1,337,000 gallons
5	10,301,000 gallons	8,680,000 gallons	1,621,000 gallons
6, 8	14,685,000 gallons	14,057,000 gallons	628,000 gallons
7	13,378,000 gallons	10,894,000 gallons	2,484,000 gallons
9, 12	13,660,000 gallons	12,400,000 gallons	1,200,000 gallons
10	5,655,000 gallons	4,664,000 gallons	991,000 gallons
13, 14	22,181,000 gallons	21,690,000 gallons	491,000 gallons
15	29,482,000 gallons	23,559,000 gallons	5,923,000 gallons
17	7,360,000 gallons	6,234,000 gallons	1,126,000 gallons
18	10,790,000 gallons	9,944,000 gallons	846,000 gallons
Total	174,780,000 gallons	153,505,000 gallons	21,275,000 gallons

$$\frac{\text{Saving } 21{,}275{,}000}{174{,}780{,}000} = 12.2 \text{ per cent}$$

Cost of Pitometer Gaugings	$22,950.00
Cost of Inspectors, Clerks, etc.	58,150.00
	$81,100.00

TABLE No. 4

Cost of Water Waste Work in Connection with House to House Inspection in Manhattan and The Bronx, from June to December, 1911

MONTH	INSPECTORS, CLERKS, ETC., IN CONNECTION WITH HOUSE TO HOUSE INSPECTION	PITOMETER FORCE	FINES IMPOSED FOR FAILURE TO REPAIR LEAKY FIXTURES	TOTAL COST AFTER DEDUCTING FINES
June	$10,300	$5,050	$736	$14,614
July	13,300	5,050	11,092	7,258
August	13,800	5,300	5,258	13,842
September	10,100	3,350	6,320	7,130
October	6,150	3,350	4,446	5,054
November	3,300	850	728	3,422
December	1,200		604	596
	$58,150	$22,950	$29,184	$51,916

Table No. 5

Measurement of Flow in Districts in Boroughs of Manhattan and Bronx Tested for Underground Leakage—to October 1, 1912

District	Boundary of District				Rate in Gallons per Day		
					Total Flow into District	Amount Unaccounted for	Amount Checked
1	E. 24th St.	East River	E. 17th St.	Ave. A. & Ave. C.	818,000	374,000	300,000
2	E. 17th St.	East River	E. 11th St.	Ave. C. & Ave. D.	835,000	500,000	350,000
3	E. 36th St.	East River	E. 24th St.	1st Ave.	811,000	335,000	200,000
4	E. 48th St.	East River	E. 42nd St.	1st Ave.	890,000	168,000	
5	E. 57th St.	East River	E. 48th St.	Ave. A. & 1st Ave.	813,000	218,000	144,000
6	E. 11th St.	East River	Houston St.	Ave. D. & Lewis St.	1,090,000	818,000	693,000
7	Houston St.	East River	Jackson St.	Mangin St.	344,000	1,000	
8	Jackson St.	East River	Jefferson St.	Cherry St.	658,000	201,000	
9	Jefferson St.	East River	Oliver St.	Cherry & Monroe	982,000		325,000
10	Oliver St.	East River	Ferry St.	Cherry St.	581,000	275,000	
11	Ferry St.	East River	Wall St.	Pearl St.	417,000	41,000	
12	Wall St.	East River	Whitehall St.	Pearl St.	1,534,000	1,222,00	1,093,000
13	W. 14th St.	9th Ave.	Bank St.	North River	964,000	506,000	
14	Morris St.	Greenwich St.	North River	North River	815,000	92,000	
15	Dey St.	Greenwich St.	Rector St.	North River	1,137,000		250,000
16	Chambers St.	Greenwich St.	Fulton St.	North River	724,000	144,000	
17	Beach St.	North River	Chambers St.	Hudson St.	672,000	40,000	
18	Canal St.	North River	Beach St.	Greenwich St.	522,000	23,000	
19	Houston St.	Greenwich St.	Canal St.	North River	778,000	83,000	50,000
20	W. 11th St.	Hudson St.	Houston St.	North River	798,000	256,000	100,000
21	W. 22nd St.	10th Ave.	W. 14th St.	North River	827,000	55,000	50,000
22	W. 30th St.	11th Ave.	W. 22nd St.	North River	962,000	568,000	
23	W. 39th St.	11th Ave.	W. 30th St.	North River	500,000	103,000	
24	W. 47th St.	11th Ave.	W. 39th St.	North River	732,000	46,000	
25	W. 57th St.	11th Ave.	W. 47th St.	North River	682,000	145,000	
26	W. 64th St.	Amsterdam Ave.	W. 57th St.	North River	1,064,000	426,000	400,000
27	E. 66th St.	East River	E. 57th St.	1st Ave.	857,000	32,000	
29	E. 79th St.	East River	E. 71st St.	Ave. A.	1,304,000	17,000	
30	W. 70th St.	North River	W. 64th St.	Amsterdam Ave.	946,000	235,000	50,000
31	86th St.	Ave. A.	79th St.	East River	774,000	9,000	
32	96th St.	1st Ave.	86th Ave.	East River	653,000	35,000	
33	81st St.	Broadway	72nd St.	Riverside Dr.	1,608,000	310,000	
34	91st St.	Broadway	100th St.	Riverside Dr.	1,419,000	411,000	85,000
35	100th St.	Broadway	91st St.	Riverside Dr.	871,000	46,000	
36	118th St.	East River	110th St.	1st Ave.	1,045,000	570,000	
37	124th St.	East River	118th St.	Pleasant Ave.	193,000	39,000	
38	East River	3rd Ave.	125th St.	East River	633,000	293,000	
39	108th St.	Broadway	100th St.	Riverside Dr.	791,000	281,000	
40	113th St.	Broadway	108th St.	Riverside Dr.	311,000	57,000	
41	119th St.	Broadway	113th St.	Riversde Dr.	455,000	11,000	
42	East River	Park Ave.	128th St.	East River	565,000	131,000	
43	Manhattan St.	Broadway	120th St.	Riverside Dr.	443,000	40,000	
44	135th St.	Broadway	Manhattan St.	Riverside Dr.	759,000	217,000	
45	Harlem River	Lenox Ave.	136th St.	Harlem River	983,000	381,000	
46	145th St.	Broadway	135th St.	Riverside Dr.	768,000	202,000	
47	13rd St.	Broadway	145th St.	Riverside Dr.	249,000	41,000	
48	158th St.	Broadway	153rd St.	Riverside Dr.	348,000	22,000	
49	Harlem River	7th Ave.	145th St.	Lenox Ave.	76,000	2,000	
50	Harlem River	Bradhust Ave.	149th St.	7th Ave.	675,000	314,000	
	Totals				37,676,000	9,236,000	4,090,000
	Leakage in River Crossings						5,700,000
	Total						9,790,000

Total cost of work, $19,000.00.

Table No. 6

Per Capita Consumption, 1880–1913, Manhattan and Bronx, and Brooklyn

Gallons Daily

YEAR	MANHATTAN AND BRONX	BROOKLYN	YEAR	MANHATTAN AND BRONX	BROOKLYN
1880	77	54.3	1900	130	87.6
1881	75.2	56.0	1901	129	85.6
1882	73	57.6	1902	129	85.6
1883	70	58.5	1903	128	84.9
1884	70	61.2	1904	132	89.5
1885	73	64.5	1905	134	91.4
1886	73	62.2	1906	133	95.7
1887	71	62.4	1907	131	101.0
1888	71	65.8	1908	126	100.2
1889	70	63.4	1909	122	95.6
1890	85	67.0	1910	120	96.8
1891	95	68.6	1911	105	91.4
1892	91	73.5	1912	104	89.3
1893	96	78.9	1913		
1894	99	71.6	First Quarter	101	79
1895	100	74.9			
1896	109	85.0			
1897	115	88.3			
1898	117	88.3			
1899	123	87.7			

Table No. 7

Borough of Brooklyn—Average Daily Consumption, 1903 to March 1913, Inclusive

Million Gallons

MONTH	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912	1913
January	107.8	116.5	123.2	121.6	134.1	141.7	133.4	142.7	151.1	156.1	122.0
February	108.6	128.2	129.5	128.7	139.8	148.8	134.4	149.7	148.9	159.1	128.9
March	105.1	114.5	123.6	126.1	134.8	138.7	134.1	142.8	147.5	148.6	122.6
April	103.0	106.6	117.8	126.3	134.0	134.4	133.5	136.3	141.0	144.0	
May	104.8	106.5	121.5	129.5	136.6	133.8	130.3	137.2	138.4	143.8	
June	100.7	109.0	120.3	134.3	139.0	144.7	137.2	139.1	138.5	143.1	
July	105.2	108.4	118.3	126.3	139.1	145.7	141.3	147.6	145.5	144.2	
August	102.0	110.3	114.7	130.0	135.0	143.9	142.0	143.7	138.9	136.1	
September	108.1	113.2	114.0	133.0	136.6	143.2	143.0	145.7	140.8	139.3	
October	103.7	112.7	115.3	124.7	134.6	142.6	138.5	143.6	132.6	136.5	
November	99.6	112.9	114.0	119.3	131.5	138.5	134.1	142.1	127.7	126.3	
December	108.5	119.5	119.1	125.5	132.8	132.0	136.2	146.7	133.2	126.7	
Average	104.7	113.1	119.2	127.1	135.6	140.6	136.5	143.1	140.3	142.0	

Table No. 8

Brooklyn—Number of Men Employed, Premises Examined and Leaky Fixtures Found During House to House Inspection, July to December, 1912

MONTHS	NUMBER OF INSPECTORS AVERAGE PER DAY	NUMBER OF CLERKS FOR OFFICE WORK AVERAGE PER DAY	NUMBER OF PREMISES INSPECTED	NUMBER OF LEAKS FOUND	NUMBER OF PREMISES RE-EXAMINED	NUMBER OF FINES IMPOSED FOR FAILURE TO REPAIR FIXTURES	AMOUNT OF FINES IMPOSED
1912							
August	35	9	8,764	9,333	1,022	18	$36.00
September	35	8	12,289	16,650	6,483	781	1,562.00
October	35	8	15,064	21,861	5,788	383	766.00
November	35	7	13,225	14,512	7,762	585	1,170.00
December	35	7	11,783	17,134	8,253	442	884.00
Total			61,125	79,490	29,308	2,209	$4,418.00

Total cost of work to December 31, 1912, $18,438.79.

Table No. 9

Saving of Water Secured by House to House Inspection in Brooklyn, as Indicated by Pitometer Gaugings of Consumption

DISTRICTS	CONSUMPTION BEFORE INSPECTION, GALLONS	CONSUMPTION AFTER INSPECTION, GALLONS	SAVING, GALLONS
1, 2	23,884,000	21,547,000	2,337,000
3[4]	13,000,000		2,200,000
4, 5	17,908,000	14,078,000	3,830,000
6, 7	12,713,000	10,343,000	2,370,000
8	9,250,000	7,750,000	1,500,000
9	6,733,000	5,396,000	1,337,000
10	9,783,000	6,807,000	2,976,000
11	9,610,000	7,110,000	2,500,000
12[4], 13[4]	12,261,000		3,065,000
17[4], 23[4]	10,049,000		2,010,000
Total	125,191,000		24,125,000

$$\frac{\text{Saving } 24{,}125{,}000}{125{,}191{,}000} = 19 \text{ per cent}$$

Cost of Pitometer Gaugings	$7,200.00
Cost of Inspectors, Clerks, etc.	29,500.00
	$36,700.00

[4] Indicates districts in which the saving has been estimated.

TABLE No. 10

Measurement of Flow in Districts in Borough of Brooklyn Tested for Underground Leakage—to October 1, 1912

DISTRICT	BOUNDARY OF DISTRICT				RATE IN GALLONS PER DAY		
					Total Flow into District	Amount Unaccounted for	Amount Checked
1	East River	Bridge St.	Plymouth St.	Main St.	1,969,000	585,000	230,000
2	East River	Hudson Ave.	Plymouth St.	Bridge St.	485,000	54,000	
3	Division Ave.	Kent Ave.	Wilson St.	East River	1,012,000	1,000	
4	S. 6th St.	Kent Ave.	Division Ave.	East River	67,000	12,000	
5	Grand St.	Kent Ave.	S. 6th St.	East River	2,564,000	248,000	160,000
6	N. 14th St.	Kent Ave.	Grand St.	East River	689,000	220,000	
7	Eagle St.	West St.	Quay St.	East River	850,000	415,000	
8	Newtown Cr.	Provost St.	Box St.	Pink St.	379,000	108,000	
9	East River	Washington St.	Water St.	East River	50,000	2,000	
10	Orange St.	Furman St.	Atlantic Ave.	East River	370,000	52,000	
11	Atlantic Ave.	Columbia St.	Sackett St.	East River	1,580,000	1,280,000	1,059,000
12	Jackett St.	Van Brunt St.	Pioneer St.	East River	1,295,000	708,000	534,000
13	Pioneer St.	Conover St.	Upper Bay	East River	188,000	112,000	
14	Dikeman St.	Otsego St.	Erie Basin	Van Brunt St.	443,000	139,000	198,000
15	Degraw St.	Nevins St.	Third St.	Gowanus Ca.	519,000	179,000	75,000
16	Neptune Ave.	Ocean P'kway	Atlantic Ocean	W. 37th St.	2,727,000	1,736,000	1,298,000
17	41st St.	1st Ave.	50th St.	Gowanus Ca	374,000	180,000	
18	50th St.	1st Ave.	56th St.	Gowanus Ca.	147,000	12,000	
20	5th St.	2nd Ave.	13th St.	Gowanus Ca.	390,000	192,000	
21	Butler St.	Gowanus Ca.	S. 4th St.	Bond St.	265,000	71,000	
22	S. 4th St.	Gowanus Ca.	Hamilton Ave.	Gowanus Ca.	556,000	146,000	
23	Bush St.	Gowanus Ca.	Erie Basin	Clinton St.	224,000	81,000	125,000
24	3rd Ave.	Gowanus Bay	15th St.	28th St.	394,000	123,000	25,000
26	Newtown Cr.	Whale Cr.	Greenpoint Ave.	Kingsland Ave.	590,000	00	
27	Newtown Cr.	English Kills.	Johnson Ave.	Flushing Ave.	200,000	50,000	
29	Flushing Ave.	Classon Ave.	Clinton Ave.	Wallabout Cha.	432,000	38,000	
30	Wallabout Cha.	Kent Ave.	Flushing Ave.	Taylor St.	203,000	70,000	
31	Newtown Cr.	Porter Ave.	Apollo St.	Lombardy St.	65,000	23,000	3,000
	High Pres. Dist. No. 13—750,000.—Special Test—155,000						905,000
	Totals				19,027,000	6,837,000	5,737,000

Total cost of work = $29,300.

DISCUSSION

Mr. R. O. Wynne-Roberts: The writer perused Mr. I. M. de Varona's paper on "Work Done for the Prevention of Water Waste in the City of New York and Results Accomplished Thereby" with great interest, for incidentally he has just been studying North American water works supplies.

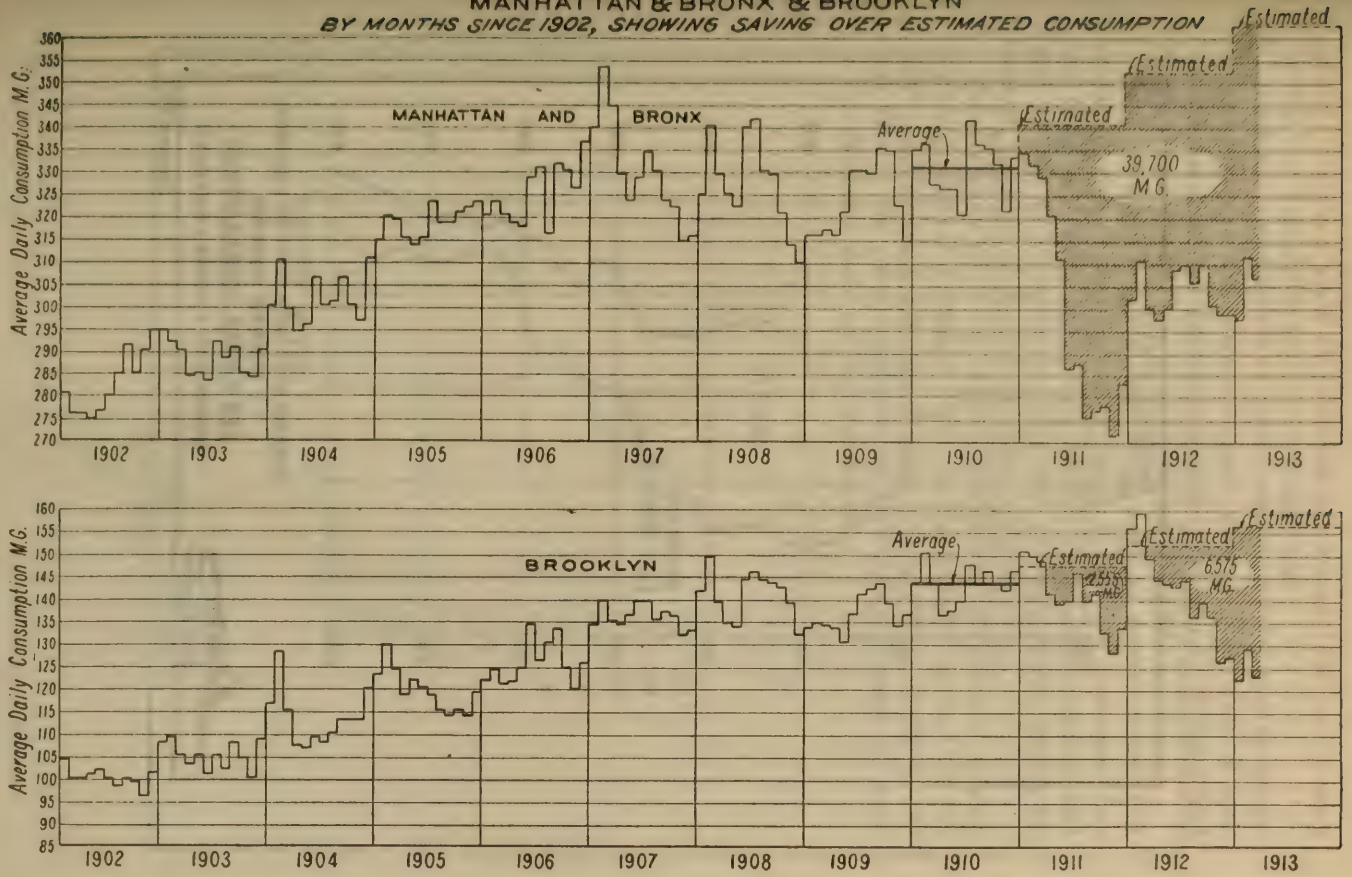
If New Orleans daily consumes only 44 gallons per capita and Minneapolis 61 gallons, there does not appear to be any tangible reason why Buffalo requires 321 and Chicago 235 gallons per capita. There will certainly be a varying demand in different cities, but it should only be a matter of a few gallons. Buffalo, however, uses over seven times the quantity consumed in New Orleans. This surely must be due to waste.

The installation of water meters on all services is advocated by some engineers, and Mr. de Varona on Page 16 states that the advisability of general adoption of meters "has been so often demonstrated and is today so generally recognized, that further exposition of proofs in support thereof seems superfluous." This is stating his case in somewhat strong terms, for on his own showing equal results can be obtained by waste detection at much less cost to the authority. He states that there is not a dissenting voice on this proposition and quotes Europe. In Europe the installation of meters is anything but general. There are many European engineers who do not advocate such a proposition. There are some European towns and cities where meters are universally installed, but are they not in the minority? It is not surprising that the public objects to meters, for the consumers have to pay more for the necessary supply, and this tends to act as a premium on insanitation. A general installation of meters imposes a heavy financial burden on the water authority, which must be paid by the consumer.

The work done in New York is certainly refreshing as it clearly indicates what can be achieved by organized waste-water detection. Space will not permit the analyzing of statistics given by Mr. de Varona. It will be interesting to know where the consumption has been reduced by universal metered supplies at the cost of doing similar work by pitometer gauging and house to house inspection and that without creating a number of penurious water consumers.

What spasmodic tests and inspections can accomplish can be

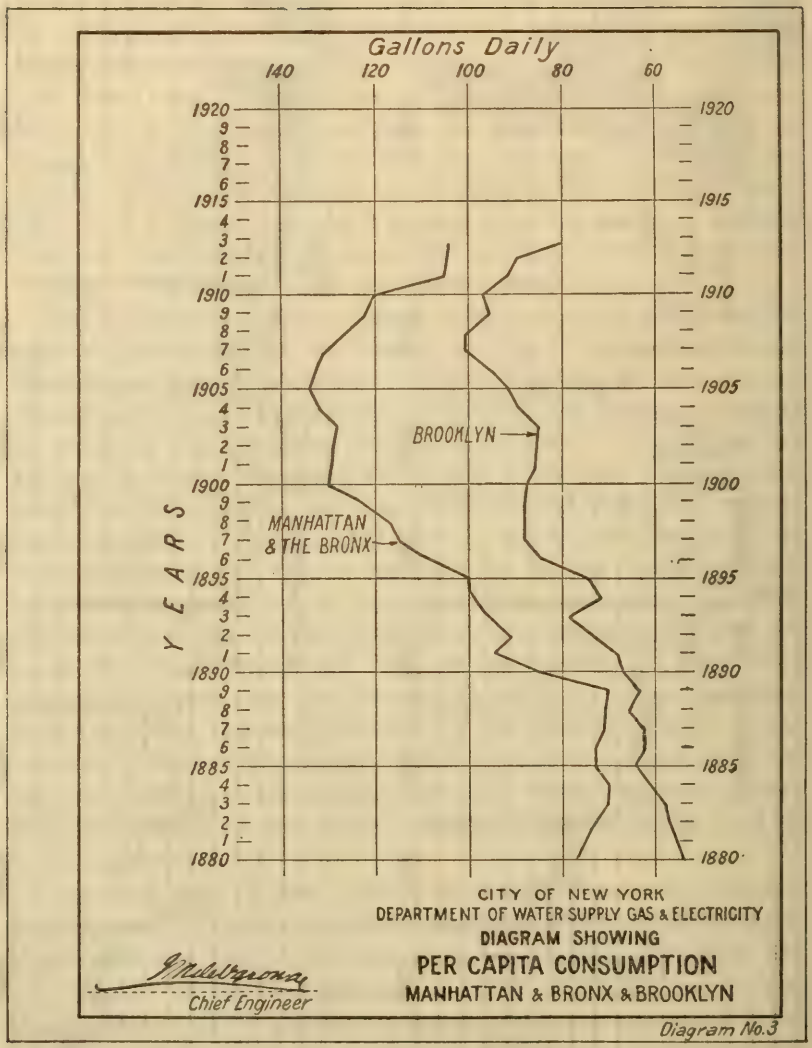
CONSUMPTION
MANHATTAN & BRONX & BROOKLYN
BY MONTHS SINCE 1902, SHOWING SAVING OVER ESTIMATED CONSUMPTION



Estimated consumption for 1911, 1912 & 1913 based on average consumption for 1910 assuming 3% increase annually due to increase in population.
Hatched portion indicates saving due to Water Waste Work.

J. Mc Strong — Chief Engineer

Diagram #2


Gallons Daily
140
120
100
80
60
YEARS
1920
1915
1910
1905
1900
1895
1890
1885
1880
BROOKLYN
MANHATTAN
& THE BRONX
CITY OF NEW YORK
DEPARTMENT OF WATER SUPPLY GAS & ELECTRICITY
DIAGRAM SHOWING
PER CAPITA CONSUMPTION
MANHATTAN & BRONX & BROOKLYN
Chief Engineer
Diagram No. 3

greatly improved upon by installing permanent bulk and district meters and organizing systematic inspections.

Abnormal consumption of water means abnormal cost of waterworks, sewerage and sewage disposal works. New York is constructing stupendous works for an additional supply of water and is also discussing great schemes of sewage disposal.

Both of these will cost enormous sums of money which will certainly give employment to a large number of engineers, but the water consumer has to pay for his unwise extravagance and also for the great losses of water due to leaky mains, which no general adoption of domestic meters would reduce.

The economy of a well ordered installation of bulk and district meters in the regular house to house inspection is proved by the figures contained in the above paper. The author deserves our best thanks for presenting such an instructive account of work in this direction done by his department.

BASIC PRINCIPLES OF GROUND WATER COLLECTION

By Chas. B. Burdick

It is the object of this paper to record the most fundamental of those principles bearing upon the collection of ground water from sand and gravel, and further to show how they have been applied, preparatory to the enlargement of two supplies more or less typical of the ground water situations frequently met with. It is understood that the remarks refer to fairly large municipal supplies; for while the basic principles do not differ with size, all the factors become important only when the rate of draft is large and constant.

At the present time about one fourth of our cities exceeding 25,000 population are supplied with ground water and probably a somewhat greater proportion of the smaller cities and villages is supplied from this source. Although great in number, but few supplies are large in the amount of water developed, Brooklyn leading with a 30,000,000 gallon development. Three or four plants produce 10,000,000 to 15,000,000 gallons daily upon the average; about a dozen pump from 5,000,000 to 10,000,000, and 40 to 50 produce 1,500,000 to 5,000,000 each. Although no late statistics are available, no doubt the number of smaller towns and villages thus supplied is very large, for small supplies are cheaply developed over a large part of the United States.

With but few exceptions the large supplies have grown from small beginnings as the possibilities of the local situations have been demonstrated through experience. In probably the great majority of cases the reasons for adequacy or inadequacy are but imperfectly understood, resulting often in disappointments in the yield from extensions and expenditures that could have been better directed with fuller knowledge of the general principles involved and the limitations of the local situation.

Most of the cities already supplied are growing rapidly, and many have approached that stage of development where additional wells do not seem to adequately meet requirements; where it seems wise to stop and consider whether further development along the

lines of the past is wise, whether further expenditures will be permanently useful, or whether a radical change in the source of supply is not warranted in the light of probable future growth.

These sources being invisible are less easily comprehended than surface water supplies and more difficult of measurement, but with fundamental principles well in mind, coupled with a fair definition of the underground situation, measurements and estimates become possible sufficiently accurate for practicable development, and the labor of ascertaining the governing conditions in many cases is not difficult. It frequently consists in making the best use of facts already available in fragmentary form coupled up and supplemented by comprehensive tests and the intelligent consideration of records.

It is intended to record the principal results of two studies that have been made to answer the questions raised above. These particular supplies have been selected because they typify two quite different ground water situations, a dissimilar local geology, and methods of development which, while differing materially, probably represent the best that could be done under the circumstances prevailing.

As there are several general principles common to both supplies, it will materially assist to mention these matters and to outline their effects upon the general ground water problem before considering the supplies in detail, and while these matters are fairly well understood by those most conversant with water supplies, a brief review of them will probably make the descriptions which follow more clear.

GROUND WATER IN NATURE

All ground water necessarily originates in rainfall, a portion of which finds its way at once over the ground surface through the streams to the sea. Another portion is at once evaporated from the surface of the ground or is absorbed by vegetation, and the third portion enters the soil. A part of this seepage is recovered by the roots of vegetation or is drawn to the surface by capillarity and evaporated, but a more or less constant supply after penetrating to a depth of 4 or 5 feet serves to replenish the store in the ground.

The surface of the earth must be regarded as more or less permeable, depending upon the openness of the materials forming the earth's crust. These materials vary from the igneous rocks, usually quite deep, except in mountainous regions, the clays, shales and usually the limestones which are nearly impervious, to the most

open and porous of coarse gravels. While all these materials, lying at considerable depths, are saturated, it is usually only in the sands and gravels that the conditions are sufficiently open to permit the ready passage of water. Where pervious conditions exist, the deep subsoil having been saturated through the rainfall of ages, the replenishment of ground water at the higher elevations causes the subsoil reservoirs to overflow at the lowest outlet, resulting in springs at the low places or seepage into the beds of streams, lakes or the ocean.

The rainfall, and hence the ground replenishment, being more or less constant, the travel of the subsoil water in undisturbed natural conditions follows the path of least resistance, moving the most rapidly in the coarser materials from the point where it enters the ground to its destination, and as would be expected, the ground water plane stands higher than the water courses and slopes toward them. This is the condition that prevails in most well watered localities. There are exceptions however in the case where sudden rises in river levels temporarily hold back the ground water, even permitting the reversal of flow from the stream back into the subsoil, and also in arid regions where the streams forsake their courses and travel through the underlying pervious materials in the river valley at such times as the flow of the stream is less than the capacity of the underlying materials.

EFFECT OF DEVELOPMENT

Almost any practicable ground water development has the effect of changing the natural ground water conditions in that the surface of the ground water is depressed adjacent to the collecting system, thus producing a flow toward the collecting system not only along the path that the ground water formerly took, but also drawing in more or less ground water from all directions even from the downstream side to a greater or less extent, for ground water slopes are usually relatively flat, and the several feet in reduction in head at the collecting system are usually sufficient to produce a slope toward such system from all directions. The larger the draft of water and the deeper that the surface of the ground water is depressed, the larger the area thus influenced.

Most developments are made upon the lowest ground available for the reason that the ground water contours in general follow those of the ground surface, and by locating a collecting system

upon the low ground, a larger gathering area is utilized. The low places are also the usual location of the streams, and as these generally occupy their ancient channels there are here usually present the most porous materials, sand and gravel, if any are to be found in the locality. If the bed of the stream cuts into these porous materials as is frequently the case, an outlet for the ground water is formed in the state of nature and when a collecting system is inaugurated an important modification in the natural conditions occurs.

If the ground water in the collecting system is depressed below the surface of the stream as is usually the case, the collection of the ground water in the vicinity is stimulated, and in addition there is a tendency to reverse the flow of ground water between land and stream, producing an inflow from the stream to the collecting system. There are some situations where this reversal of flow is not present; particularly where the stream flows upon a clay bed overlying the sand or gravel stratum from which the ground water supply is developed.

The rapidity with which the water may enter the ground from the stream obviously depends upon the available head, the coarseness of the material forming the stream bed, and it is also modified by the turbidity of the water and the relative duration of various turbidities; also the velocity of the stream as affecting the amount of deposits.

It is well known that a water filter constantly operated becomes choked and is necessarily cleaned if operations are continued. Precisely this situation exists in the stream beds and it is fortunate for the quality of the ground water that this is so, for it has a tendency to rapidly seal those places where for reasons of high porosity or steep gradient, the filtration rates are most rapid; thus in a way tending to distribute the seepage more uniformly over a larger area.

Although the stream bottom may become comparatively impervious, such water tightness is comparative only, and the large areas subject to filtration adjacent to the ground water collection system produce considerable water even under adverse conditions.

FUNDAMENTALS OF YIELD

In any collecting system there must be:

1. A gathering ground sufficient to produce the required water; that is, an area sufficient in extent so that the absorbed rainfall

made uniform by ground storage and supplemented by infiltration, if any, is sufficient at all times to meet the maximum draft of the collecting system.

2. That the location, character and depth of the impervious materials between the gathering ground and the collection system are such as to permit the passage of ground water at the rates demanded.

3. That the collecting system is so designed that the maximum rate of draft can be secured under the most unfavorable ground water levels that are likely to occur.

If any one of these three requisites is lacking, the supply must of necessity be measured by the weakest link in the chain.

In planning new developments or in materially increasing old ones, it is wise to select locations where present demands can be accommodated, and wherever possible, a large margin left for future demands, and it is further unwise to attempt to develop a gathering ground too closely to its estimated capacity. A factor of safety should be allowed in amount depending upon the accuracy with which the underground conditions are determined.

GATHERING GROUND

The extent of the gathering ground is necessarily dependent upon the area tributary to collecting works, and is affected by the topography, the extent, thickness and character of the water carrying strata, the extent of the collecting system and the depth to which the ground water is depressed at the place of collection. More frequently one of these factors is determining, and it is but seldom that all must receive much consideration. It is usually not difficult to determine the area with reasonable accuracy.

The yield is further dependent upon the rainfall and the readiness with which it is absorbed. In ground water collecting areas these factors do not differ as widely as might be expected, for such collecting systems are projected in localities where more or less experience has indicated favorable conditions. In the matter of capacity, the least yield is of importance, although where the depths of water bearing material are great, the average of a series of years may be used. Monthly rainfalls are of small significance except that a certain depth of storage should be reserved for the well known seasonal variations, particularly in absorption, for apparently a very large part of the ground water accretion occurs in the winter and spring.

Experience seems to indicate that under reasonably favorable conditions, from one quarter to one half of the rainfall may be depended upon to replenish the ground water. This experience is in well watered country, in localities favorable to ground water use. A local index is furnished by the low water flow of certain streams, particularly brooks or other water courses having a drainage area approximately coincident with that practicable for ground water development. In some situations the geological conditions may be uniform over a comparatively large area as in certain regions where the glacial work has been uniform. In such localities the minimum stream flow is a good index.

Table A indicates the approximate absorption capacity of several underground water sheds where capacity has been demonstrated by usage.

TABLE A

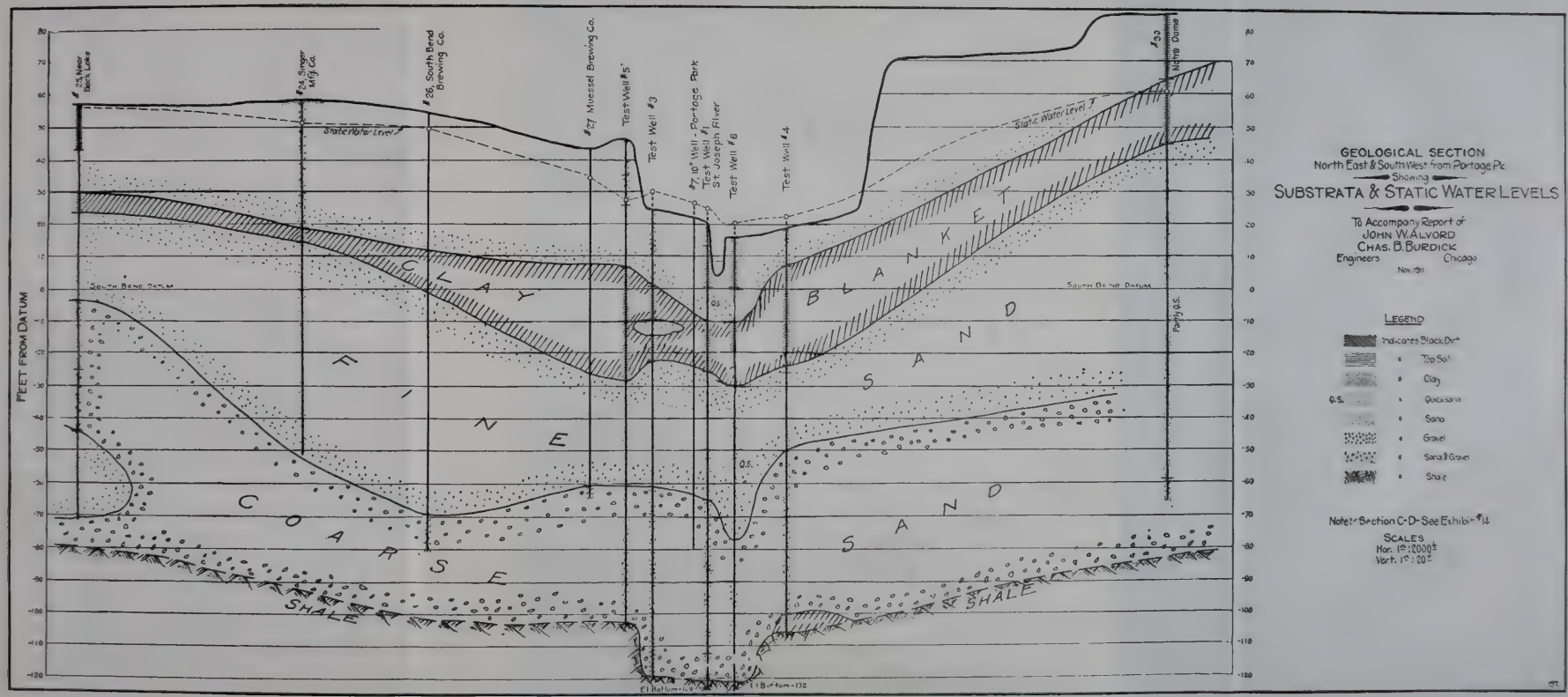
Showing Relation Between Rainfall and Ground Water

PLACE	MEAN ANNUAL RAINFALL INCHES	INCHES GROUND WATER COLLECTED	RATIO GROUND WATER TO RAINFALL
Long Island	45	14 to 24	30% to 50%
Holland, Europe	26	8 to 13	30% to 50%
[1] Holland, Mich.	34	8.72	26%
Philadelphia, Pa.	43	5 to 8	12% to 18%
[1] Jeffersonville, Ind.	45	3.6	8%

NOTE:
12 inches per year collected = 570,000 gallons day per square mile.
8 inches per year collected = 380,000 gallons day per square mile.
6 inches per year collected = 285,000 gallons day per square mile.
[1] Watersheds observed not fully developed.

TRANSMISSION CAPACITY

In addition to a gathering ground and an ample collecting system, there must of necessity be present coarse materials of such nature and extent that water may travel from its source to place of collection. Sand and gravel are the only transmission media of significance in municipal water supply. It has been demonstrated that the flow through such materials departs from the law of flow through pipes and follows more nearly that through capillary tubes. The flow in sand and gravel at the velocities occurring in the ground varies with the first power of the head or slope. This law is evidenced by the practicable draft from the wells which increases in


#25, Near Back Lane
#24, Singer Mfg. Co.
#26, South Bend Brewing Co.
#27 Muessel Brewing Co.
Test Well #5
Test Well #3
#7, 10" Well, Portage Park
Test Well #1
St. Joseph River
Test Well #6
Test Well #4
#30
Notre Dame
Static Water Level
State Water Level
South Bend Datum
FEET FROM DATUM
CLAY
FINE
COARSE
BLANKET
SAND
SAND
SHALE
SHALE
Q.S.
Q.S.
Purity U.S.
El. Bottom-132
GEOLOGICAL SECTION
North East & South West from Portage Pk.
Showing
SUBSTRATA & STATIC WATER LEVELS
To Accompany Report of
JOHN W. ALVORD
CHAS. B. BURDICK
Engineers
Chicago
Nov. 1911
LEGEND
Indicates Black Dirt
Top Soil
Clay
Quicksand
Sand
Gravel
Sand & Gravel
Shale
Note: Section C-D See Exhibit #14
SCALES
Hor. 1" : 2000'
Vert. 1" : 20'

direct proportion to the amount that the water surface in the well is lowered through pumping.

The capacity of a given material depends upon its porosity and to a large extent upon its coarseness, it having been demonstrated that the velocity of flow under a given head varies approximately as the square of the effective size of the grains in the material.

Through the investigations, formulae and coëfficients developed by Darcy, Krober, Hazen and Slichter, and particularly the application of these investigations to practical ground water problems as clearly outlined by Prof. F. E. Turneaure,[1] it is practicable where the conditions are well defined and fairly uniform to approximate the capacity of the water transmission medium, and such computations are frequently of great use not only in ascertaining whether it is practicable to draw a stated quantity to a desired locality, but also in the design of the means for collecting the ground water.

The formula suggested by Professor Turneaure is a simplification of a formula of Hazen by the elimination of the temperature coëfficient, as most ground waters have about the same temperature, and embodying all variables except slope in a coëfficient which is varied to allow for the effective size of the sand and its porosity. The effect of porosity is based on investigations by Slichter.

The formula is quite simple, velocity in feet per day being equivalent to the product of the slope of the ground water hydraulic gradient and a coëfficient, selected from tables, based on effective size and porosity. Knowing velocity and porosity, which represents the void space open to the travel of water, quantity can be computed from the dimensions of the water bearing stratum.

The important effect of "coarseness" is well illustrated by the following table prepared from Professor Turneaure's values for a porosity of 30 per cent.

EFFECTIVE SIZE OF SAND OR GRAVEL IN MILLIMETERS	APPROXIMATE DESCRIPTION	VALUE OF COEFFICIENT EQUIVALENT TO VELOCITY IN FEET PER DAY ON A SLOPE OF 1 TO 1 30% POROSITY
0.10	Very fine sand	43
0.20	Fine sand	171
0.30	Medium sand	384
0.40	Coarse sand	681
0.50	Torpedo sand	1,066
1.00	Fine gravel	4,260
2.00	$\frac{1}{10}$ inch gravel	17,050
3.00	$\frac{1}{8}$ inch gravel	38,400

[1]Public Water Supplies—Turneaure & Russel.

It should be noted that the effective size as stated refers to the smallest 10 per cent of a given sample, according to the definition of Hazen; the small grains, tending to clog the interstices, having a governing effect.

The relation of flow to size in the above table indicates that under any given slope one foot of torpedo sand will transmit as much water as 25 feet of very fine sand, and 1 foot of fine gravel (size 1.0 m.m.) is approximately equivalent to 100 feet of very fine sand.

It is, therefore, the coarser materials only that are of much significance in a large water collecting system, and frequently the finer sands may be neglected or given nominal values without materially affecting the problem in hand.

Where the underground conditions are known as to depth and character of water bearing material, it is practicable to demonstrate the value of the flow coëfficient by pumping a test well and observing the hydraulic gradient of the ground water. In several cases where the effective size of the water bearing material has been noted through the sifting of numerous borings, the coëfficients tabulated above have been approximated. If the purpose in hand requires an approach to accuracy, such tests of the water bearing materials in their original situation are necessary; and the coëfficients thus developed eliminate inaccuracies in a number of other determinations in that the reasoning is then direct from quantity drawn to hydraulic gradient.

SOUTH BEND

The ground water supply at South Bend illustrates the situation where the water is collected upon uplands and fed through a stratum of coarse sand to the locality of the development in the valley of the St. Joe River. The water bearing stratum is overlaid by a heavy clay blanket upon the low ground occupied by the greater portion of the city, serving to separate the river water from the ground water in this locality, and, together with the elevated water source, producing a head at certain low places adjacent to the river in the amount of from 12 to 20 feet above river level, and 8 to 10 feet above ground surface. Under these conditions it is practicable to develop a large amount of water quite cheaply without any seepage from the river, and although the collecting works are located within the city near the center of the distribution system, the clay blanket or the depth at which the supply is drawn, or both, apparently prevents local pollution.

Figure 1 gives a fair idea of the local topography, the relation of the gathering ground to the collecting system, the ground water contours and the local surface geological classifications.

Figure 2 is a cross section of the valley showing the distribution of water bearing materials and a profile of the surface of the ground water.

Figure 3 shows the condensed data as to relative elevations at the two pumping stations, together with the delivery curves of the well systems.

Table B is a tabular summary of numerous tests that show the delivery capacities of various groups of wells together with the principal governing conditions.

The water supply is developed by two stations in which the high lift pumping engines are directly connected by suction to systems of driven wells from 4 to 10 inches in diameter, and from 80 to 116 feet deep. Water has been supplied from this source since 1886. The consumption of the city in 1910 averaged 4,730,000 gallons per day, with an average consumption for the maximum month of 7,300,000, and as no storage is provided, the rate of domestic consumption approximates 14,000,000 gallons per day for a few hours at the peak of load.

The gathering ground lies upon the Maxinkuckee moraine, through which the St. Joe River has cut in the city of South Bend, and some water is also doubtless collected on the end of the Valparaiso moraine westward from the city. These uplands are typical moraines, abounding in hummocks and saucer-like depressions with no well defined drainage lines. At certain places growing corn can be seen in the bottoms of bowl shaped depressions several acres in extent, with no drainage except the subsoil. This situation is ideal for the collection and storage of rainfall.

It is estimated that under the most unfavorable circumstances the gathering capacity of this watershed would not be less than 20 to 30,000,000 gallons per day.

Studies were made to demonstrate the transmission capacity of subsoils between the gathering ground and the river valley by tabulating and platting numerous borings that had been made by the city and the wells constructed by individuals and manufactories, and there seems no doubt that this capacity equals or exceeds that of the gathering ground. This is further evidenced by the absence of springs upon the higher ground adjacent to the river and on the slopes of the moraines, a condition that would be inevitable if the outflowing path of the water were restricted.

TABLE B

Table Showing Specific Capacity of South Bend Wells

(i. e., Yield in gals. per min. per ft. of draft measured from static water level.)

PLACE	NO. OF WELLS SIMULTANEOUSLY PUMPED	SIZE	LENGTH STRAINERS	MESH STRAINERS	APPROX. SPACING	AREA OF GROUP	SPECIFIC CAPACITY PER WELL	REMARKS
Portage Park	1	10″	16′	Coarse			32	Test new well in 1911
N. Station	1	6″	10′	Fine			38	Best of 5 wells when new in 1895
N. Station	1	6″	10′	Fine			31	Poorest of 5 wells when new in 1895
Central Station	1	10″					30	Test in 1906, new well
N. Station	2	10″	16′	Coarse	4′		37	Koontz wells, 1 yr. old. Tested 1911
N. Station	4	10″	16′	Coarse			25	Koontz wells, 1 yr. old. Tested 1911
N. Station	6	10″	16′	Coarse			22	Koontz wells, 1 y.. old. Tested 1911
N. Station	8	10″	16′	Coarse			17	Koontz wells, 1 yr. old. Tested 1911
N. Station	10	10″	16′	Coarse			15	Koontz wells, 1 yr. old. Tested 1911
N. Station	12	10″	16′	Coarse	4′ to 6′	6′ x 20′	13	Koontz wells, 1 yr. old. Tested 1911
Central Station	12	4″ to 10″	9′ to 12′	Fine	50′ to 70′	80′ x 310′	7.5	South group, av. age 16 yrs.
Central Station	19	4″ to 10″	9′ to 12′	Fine	10′ to 15′	60′ x 90′	5.	North group, av. age 23 yrs.
N. Station	16	6″ to 10″	10′ to 16′	Fine		1000′ x 550′	7.3	All old wells, av. age 15 yrs.
N. Station	34	6″ to 10″	10′ to 16′	Fine		1000′ x 550′	4.0	All old wells, av. age 15 yrs.
N. Station (all)	46	6″ to 10″	10′ to 16′	Fine to coarse		1000′ x 550′	5.05	Ave. age 11 yrs. (incl. Koontz wells)
Centra Station	29	4″ to 10″	9′ to 12′	Fine		310′ x 320′	5.3	Ave. age 20 yrs.

As the capacity of the present collecting works was taxed in seasons of maximum consumption and further extensions were necessary, it had been intended to construct a third pumping station about one mile downstream from the north station. As a result of this investigation, the construction of the new station was abandoned, it being concluded that improvements to the existing works would suffice for the next generation. The recommended improvements, now practically completed, include a more efficient well system where the old wells were lacking in capacity through deterioration in the strainer system which could not be repaired by reason of the construction of the wells; the utilization of storage for tiding over the peak loads, and the installation of additional pumping equipment. The north station is located in a city park and is operated by steam. The central station closely adjoins the business district and is operated by water power. It is rather unusual to find a ground water collecting system located in the heart of a growing city with the advantages in the distribution of water that accompanies such a location. Apparently there is sufficient ground water available to supply an indefinite future growth by sufficiently extending the collecting system downstream from the north station. About two miles upstream the geological conditions change materially. The city of Mishawaka, which adjoins South Bend on the east, has had considerable difficulty in locating a satisfactory ground water.

DES MOINES

A very different ground water situation is found at Des Moines, Iowa. Geologically, this locality is in the coal measures. The only sand and gravel in the locality lie in the flood plains of the Des Moines and Raccoon rivers which unite within the city.

The Des Moines Water Works are located on the Raccoon River at the southwestern edge of the inhabited area of the city, but less than a mile distant from the business center.

Geologically there is no connection between the ground on which the city is built and the sand and gravel stratum from which the municipal water supply is obtained, the city lying upon shale and clay hills through which the ancient Raccoon River cut its channel to a depth of about 100 feet and a width of one mile. This channel has since been refilled with the sand and gravel accumulation from the glacial wash to an average depth of about 20 feet, and later overlaid with finer alluvial deposits through which the comparatively

small river now winds back and forth. This river valley on account of its low elevation is subject to floods and is uninhabited, except for agriculture, adjacent to the water works collecting system.

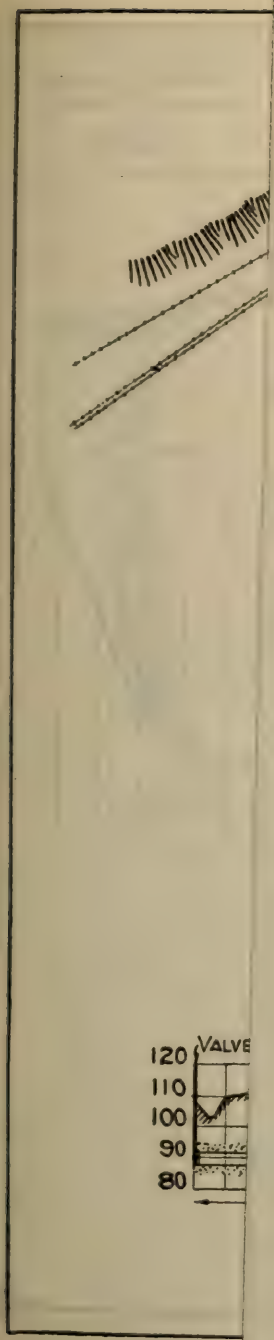
The supply is derived from a series of horizontal collecting galleries crossing and in general paralleling the river at a depth of about 15 feet below low water. These galleries aggregate about 6500 feet in length at this time. They lead to a pump well at the water works station from which the high lift pumping engines discharge the water directly into the city distribution system.

Figures 4, 5 and 6 show the geological cross sections of the river valley and the ground water contours for a distance of three miles upstream and the contours adjacent to the gallery system as it existed in 1907, the time when this investigation was made. The average pumpage at that time was about 3,800,000 gallons per day. The pumpage in 1912 averaged 5,500,000 with maximum rates of 7 to 10,000,000. They have at times been materially increased when fighting a large fire, as there is no storage except in the collecting system. It has been demonstrated, however, that the large volume of saturated sand adjacent to the gallery system furnishes ideal storage that can be drawn upon at very heavy rates, 15,000,000 gallons or more for many consecutive hours.

An analysis of the water collecting system similar to that hereinbefore outlined at South Bend demonstrated beyond question that the major portion of the supply, two thirds or more, is derived from river infiltration, the surface gathering ground and particularly the transmission capacity of the valley sands being very materially inadequate to account for the amount of water that had been developed for years. A comparison of the ground water contours and the river water levels showed that about 7000 feet of river at low water is subject to infiltration, and that an average filtration rate of 100,000 gallons per acre of river bed per day would be sufficient to supply the pumpage rates noted at the time that the water contours were platted. The water bearing material is quite uniformly a coarse sand varying from .37 to .62 millimeters in effective size, and averaging about .42 millimeters.

The effective head or difference between river level and suction well level varies from 2 feet in flood to about 12 feet in the late winter. The average is about 5 or 6 feet.

That the river infiltration is the principal supply source is confirmed by the operating results. It has been observed that floods of a certain character leave the bed and bars of the river in a highly


VALVE
120
110
100
90
80

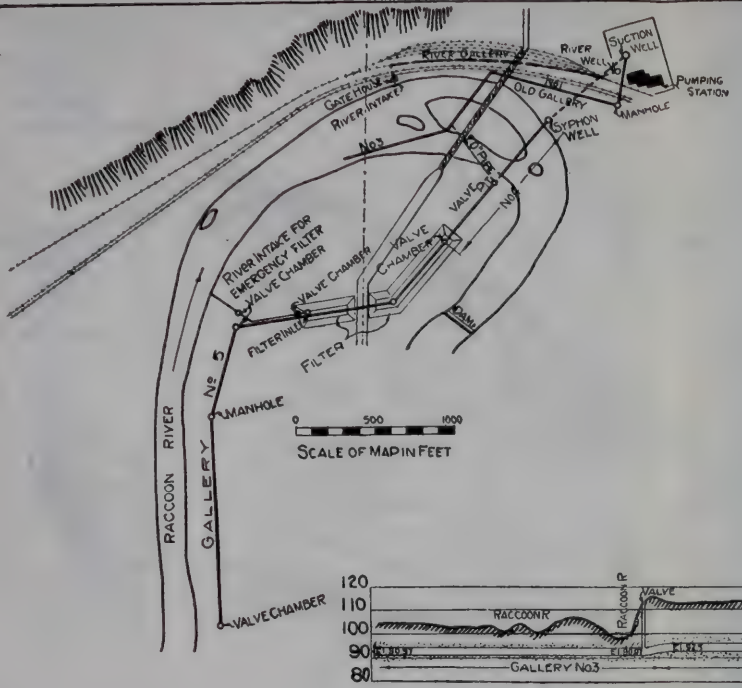
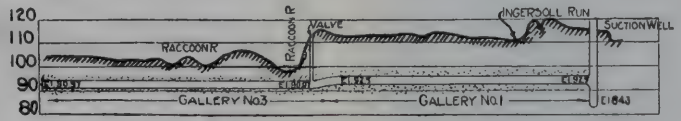
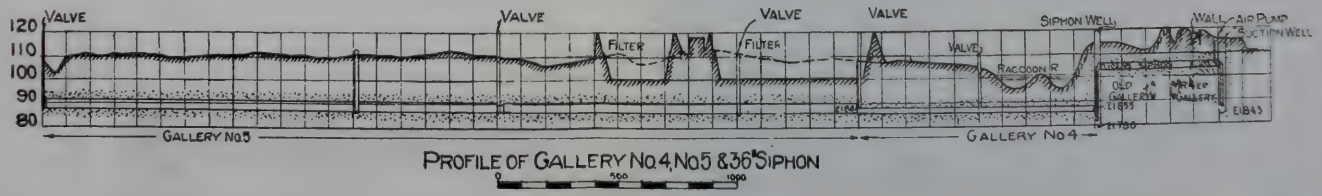


DIAGRAM SHOWING
COLLECTING GALLERIES
DES MOINES WATER CO.
DES MOINES IA.

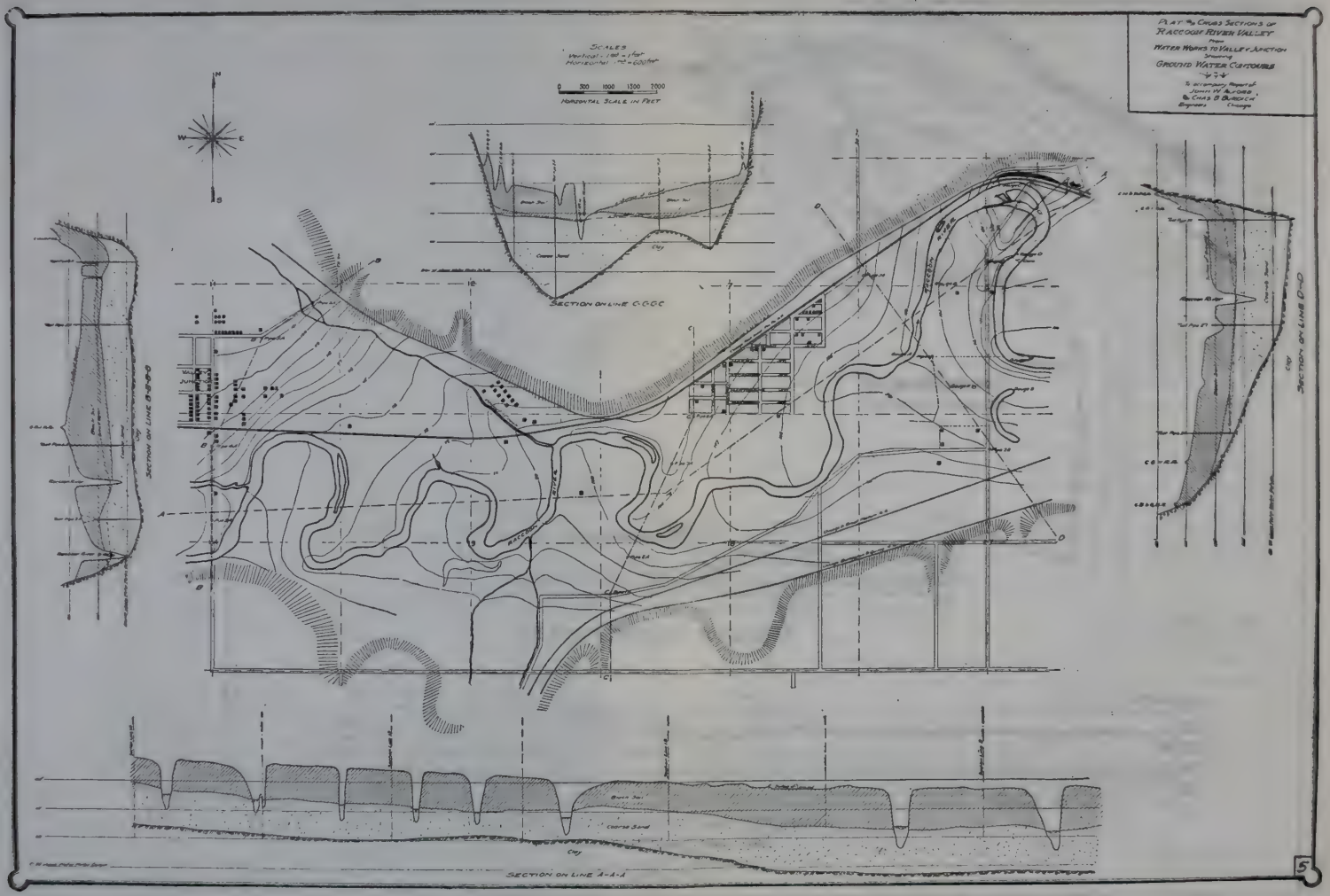


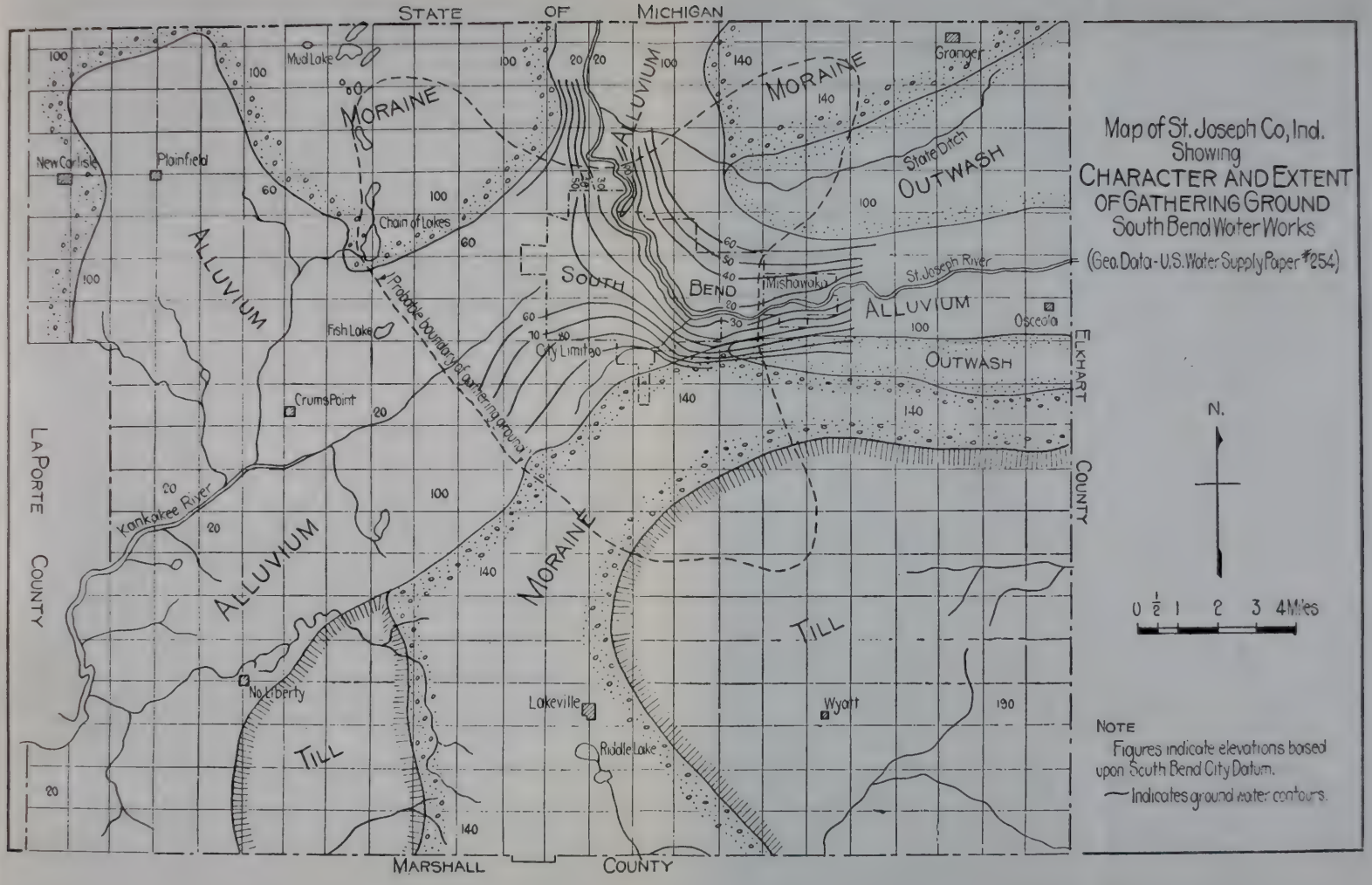
PROFILE OF GALLERIES NOS. 3 & 1



PROFILE OF GALLERY No 4, No 5 & 36" SIPHON

0 500 1000
HORIZONTAL SCALE IN FEET
(For Sections)


Plat & Cross Sections of
Raccoon River Valley
from
Water Works to Valley Junction
showing
Ground Water Contours
To accompany Report of
James H. Alford
& Chas B. Burdick
Engineers Chicago
Scales
Vertical 1 inch = 1 foot
Horizontal 1 inch = 600 feet
0 500 1000 1500 2000
Horizontal Scale in Feet
N
W
E
S
Section on line C-C-C
Section on line B-B-B
Section on line D-D-D
Section on line A-A-A
Raccoon
Creek
Valley Junction
Cover
Clay
Coarse Sand
Gravel
5


STATE OF MICHIGAN
Mud Lake
Granger
MORAINE
ALLUVIUM
MORAINE
State Ditch
OUTWASH
New Carlisle
Plainfield
Chain of Lakes
ALLUVIUM
Probable boundary of gathering ground
SOUTH BEND
Mishawaka
St. Joseph River
ALLUVIUM
Osceola
Fish Lake
City Limits
OUTWASH
ELKHART COUNTY
Crums Point
LA PORTE COUNTY
Kankakee River
ALLUVIUM
MORAINE
TILL
No. Liberty
Lakeville
Wyatt
Riddle Lake
TILL
MARSHALL COUNTY
Map of St. Joseph Co, Ind.
Showing
CHARACTER AND EXTENT
OF GATHERING GROUND
South Bend Water Works
(Geo. Data - U.S. Water Supply Paper #254)
N.
0 1/2 1 2 3 4 Miles
NOTE
Figures indicate elevations based upon South Bend City Datum.
— Indicates ground water contours.

"silted" condition, producing low water levels in the galleries upon the recession of the flood. Floods of the same turbidity vary greatly in this result, largely on account of the effect on velocities of the prevailing stage in the Des Moines River at the junction with the Raccoon two miles below. Although this condition occurs but seldom, it had been the custom to stimulate infiltration by cleaning off the bars adjacent to the collecting system, but as this procedure permitted no control of the filtration rate, the improvements of 1908–1910 included the preparation of a special filter area (0.85 acre) protected by dikes in which the filtration rates can be controlled.

The growth of collecting system and the amount of water developed are as follows:—

Growth and Capacity of Gallery System

YEAR	FEET OF GALLERY IN USE	DAILY PUMPAGE AVERAGE	MILLION GALLONS MAX. MONTH
1884	260	1.8	1.9
1885	760	1.7	2.2
1886	1,069	1.8	2.2
1887	2,723	2.2	3.8
1894	3,973	3.8	3.5
1897	2,319	—	3.8
1905	3,319	3.9	3.9
1912	6,469	5.5	6.0

As a result of this investigation, material additions to the collecting system were made with confidence as to the yield and the permanency of the expenditures.

The supplies at South Bend and Des Moines may be regarded as typifying the two extremes in the immediate source of ground water. The upland source upon the one hand not affected by percolation from bodies of surface water, and upon the other, a water derived very largely from infiltration. Between these extremes lie very many supplies in which both sources are drawn upon, to a greater or less degree. Where broad policies of development must be laid down, an acquaintance with the local sources is vital to success.

DISCUSSION

R. O. Wynne-Roberts: The investigations which the speaker made for the city of Regina in 1911 are almost indentical with those Mr. Burdick made at South Bend and the results are almost the same.

The speaker investigated an area of about 800 square miles with the view of ascertaining the water bearing condition of about 200 square miles of watersheds. The district is entirely of glacial formation, of a chaotic nature. After making the investigation, he advised the City Council to sink wells on a low patch of land about 8 miles outside the city. Twenty 5 inch by 7 inch wells have been sunk to depths ranging from 65 to 192 feet and of these, fourteen are flowing. Some of these wells discharged 300,000 to 500,000 imperial gallons of water, but as the flow was too great, we had trouble in keeping them clear. The watershed we are now developing is 72 square miles in area, the mean rainfall is about 16 inches but in years of drought it will fall to about 10 inches. The speaker estimated that we ought to obtain a little more than one inch of rainfall, that is over ten per cent, which appears to coincide with the results mentioned in Mr. Burdick's paper. The highest part of the water shed stands about 350 feet above the point where we are sinking the well.

It will be interesting to have more information concerning the area and height of the watershed at South Bend.

In a paper sent to the Illinois Water Supply Association,[1] you will see that we raised some points as to the hardness of the water, use of screens, etc.

It will be interesting if Mr. Burdick will give a mineral analysis of South Bend water, and if very hard, is it softened by any process?

Mr. Chas. B. Burdick: Replying to the inquiry of Mr. R. O. Wynne-Roberts,—

The investigation at South Bend indicated that there is substantially 100 square miles of drainage area that could be made tributary to the collecting works in the valley of the St. Joe river adjacent to the city, including the two pumping plants at present in operation. About ninety per cent of this area consists of glacial outwash, moraine and river valley alluvium, highly absorptive materials. All of this area could probably not be made tributary

[1] Proc. Ill., W. S. A., 1913, p. 227.

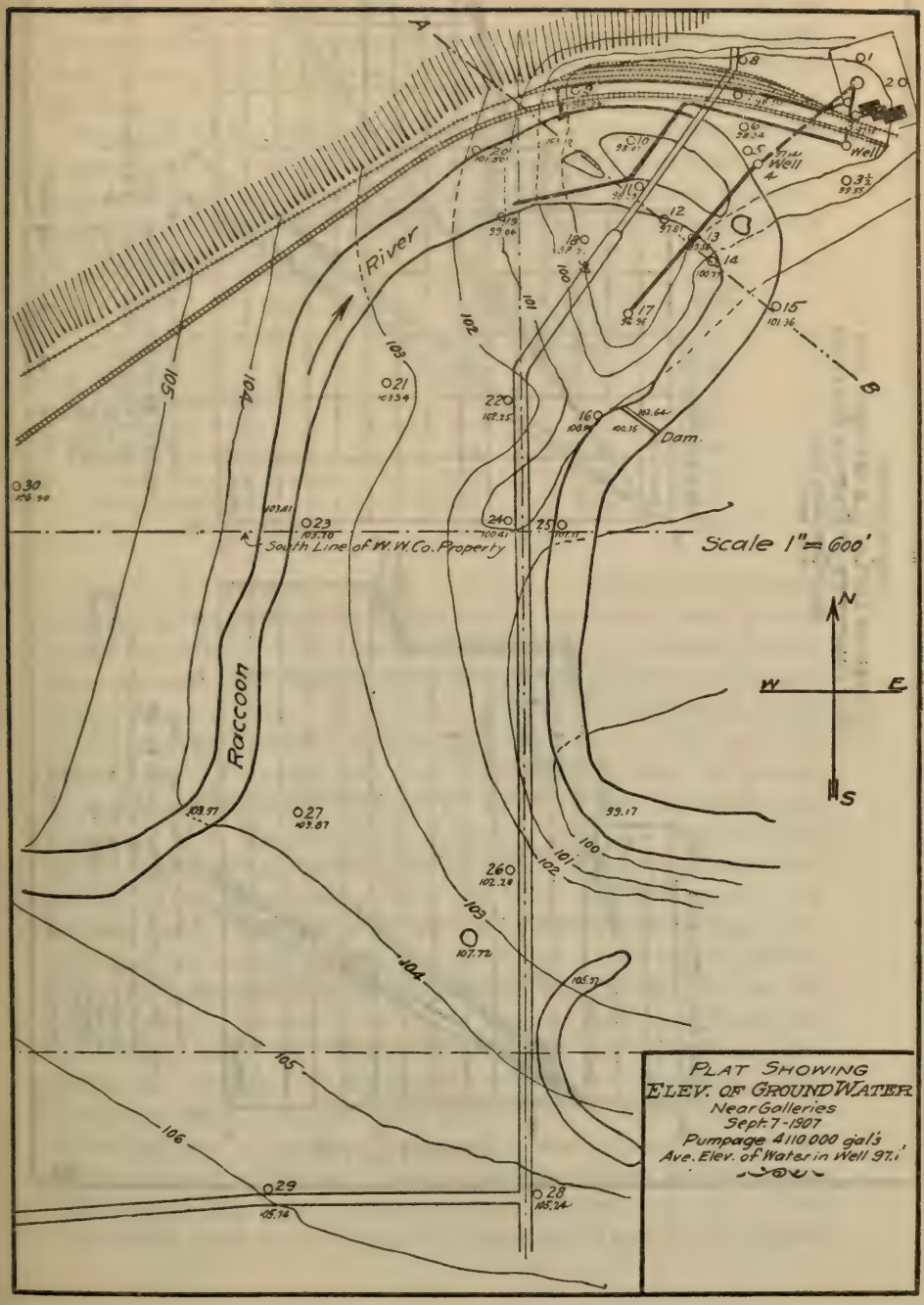
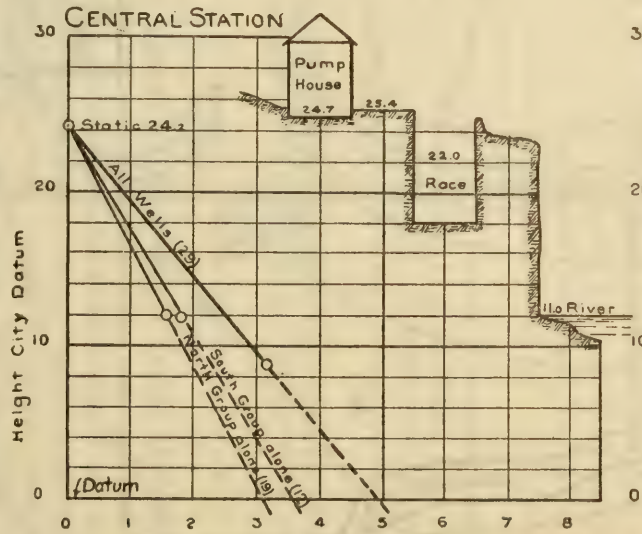

A
B
River
Raccoon
Well
Well
Dam.
South Line of W. W. Co. Property
Scale 1" = 600'
N
W
E
S
PLAT SHOWING
ELEV. OF GROUNDWATER
Near Galleries
Sept. 7-1907
Pumpage 4110000 gal's
Ave. Elev. of Water in Well 97.1'

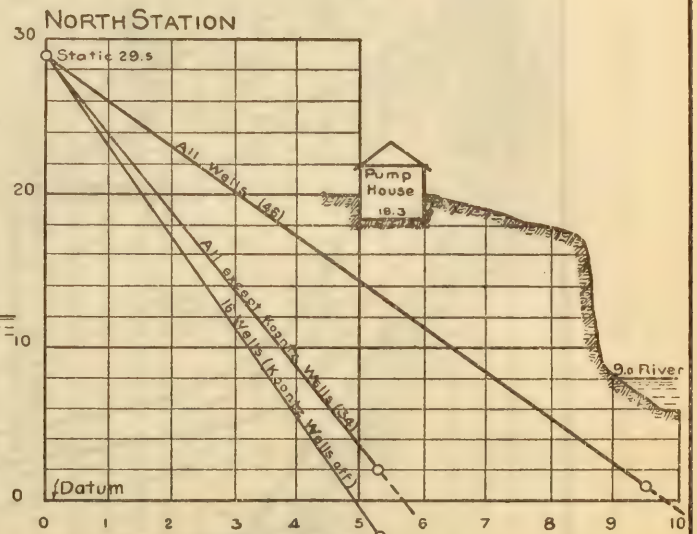
Diagram Showing
GOVERNING DATUM ELEVATIONS AND
TEST CAPACITIES OF PUMPING STATIONS
South Bend Water Wks.



WATER BEARING STRATUM 20' to 30'

14 - 4" Wells sunk in 1886, 9' Screens - Depth 114'
16 - 6"-8" " " " 1891, 9' " - " 113' to 116'
6 - 10" " " " 1906, 12' " - " 98' to 110'
36 Total

29 Wells in service during test



WATER BEARING STRATUM 38'

30 - 6" Wells sunk in 1895, 10' Screens - Depth 80' to 90'
4 - 10" " " " 1906, 6' " - " 80' " 90'
12 - 10" " " " 1910, " " 98' " 102'
46 - Total

All Wells in service during test

604

to the present pumping stations. To develop the whole area the collecting works would necessarily be spread out over a greater length of the river. The whole area, however, is in one watershed strictly speaking.

In regard to the character of the water, no mineral analyses are available. The sanitary analyses in the writer's possession, however, show total solids and hardness which give a line on the mineral character of the water, the following characteristics being shown in about a dozen analyses.

Water	*Date*	*Parts per Million Total Solids*	*Parts per Million Hardness*
Tap water	1907	366	246
Tap water	1909	376	230
Portage Park well	1911	516	210
Echman St. well	1910	464	258
North Pumping Station	1911	290	208
Central Pumping Station	1911	522	242
Portage Park well	1911	282	208
Well near Beck's Lake	1911	280	212

Mr. A. A. Reimer: A very interesting question has recently come up in New Jersey in a legal way in connection with ground water collection. The East Orange supply is obtained largely from artesian wells sunk in the terminal moraine of the early and latest glacial periods. When starting work on those wells about nine years ago, the East Orange authorities had as their legal authority the old English rule that a man can do what he pleases with his own property; that is, he can take a million gallons of water out of it, and it does not make any difference what happens to his neighbors as a result of that action. They went ahead and developed the new system, and had been operating only a few months when they were confronted by a rather serious legal complication. A farmer owning a farm about a mile and a quarter away from the pumping station charged that he had lost the use of his spring. He was in the dairy business, and used the spring for cooling milk. East Orange fought that case to a finish, and finally the decision went against the city, only to the extent, however, of nominal damages of six cents. But of course that established the rule of law that if allowed to stand, would govern all future actions. However, they decided to play a waiting game; sure enough this man came back again with another suit. That suit finally went to the Court of Errors and Appeals, the highest

court in New Jersey, and the rule of law laid down there established a new precedent in New Jersey, placing underground waters in the same position as surface waters. It practically established the law of riparian right over underground waters. East Orange was held liable for diversion of water. Of course the fact had to be first proven, so that the decision amounted only to a rule of law. It has proven an expensive proposition in the case of East Orange and here is where these remarks touch Mr. Burdick's paper. The city had to determine the extent of its underground drainage area; it had to consider soils more closely than ever before. It was not that the authorities did not want to know these things before, but they did not have to know them before, and desired to save the expense of a thorough investigation. Finally, they did investigate to the extent of a good many thousands of dollars, drilling wells all through the region and watching the rise and fall of the underground water. These observations have been carried on regularly for several years and a hydrograph has been prepared. It is intensely interesting to any one who is interested in underground waters.

In the opinion of the speaker, any intelligent engineer who makes a study of the matter, if he be fairminded, will admit that there can be no possible direct physical connection between springs or wells a mile and a quarter from the East Orange pumping station wells and these latter wells; that is, no connection intimate enough, direct enough, to cause the latter wells to affect a surface well or shallow spring a mile and a quarter away. The speaker feels sure that if he had possessed such a hydrograph seven years ago, the decision that now stands in the state of New Jersey as the rule of law for all underground water supplies would not have been written. The reason for referring to this is in order to emphasize to all who are handling artesian well systems and especially those who are getting pretty close to the limit of their well systems, not to rest content with their little batch of wells but to get outside as far as possible, for no one knows who is going to bring suit. Watch the surface wells; watch the springs and the flow of streams, anything that tells the story of the flow of the surface or underground waters; for no one knows at what moment the same trouble may arise in some other state that arose in New Jersey.

The speaker hopes that his experience may be of some benefit to others in saving money and trouble.

We pump about 3,000,000 gallons a day on an average; this is taken from a rather limited artesian basin, but one that is ample for present needs so long as it is properly conserved. This artesian basin is good for over 5,000,000 gallons, but the plant for East Orange is not the only one that is drawing from that particular basin. A private water company draws about 2,000,000 gallons a day from the same basin.

Mr. Wirt J. Wills: Inasmuch as Mr. Burdick mentioned a well water supply of about 30,000,000 gallons daily, and as the supply of Memphis is about that size, probably a few remarks concerning the plant, which is about the largest well-water plant in the United States, might be of some interest.

The strata of water bearing sand in our district, according to a survey prepared by the United States Government, extends from the middle of Illinois to the middle of Mississippi, and is about 300 miles wide at Memphis, and is tapped with wells at an average depth of about 500 feet. Of course different strata in different parts of the country are affected differently, water being taken in some cases out of the rock and others from gravel. It must be admitted that wells do interfere in flow with each other.

The writer received a copy of Mr. Burdick's paper, in which he states that when a well is bored in the sand it is like an inverted cone, extending out wider at the top and running down to a point at the bottom. A little practical experience on that line may be of use to some of you. Four years ago we put in four wells at the Old Memphis Plant, which were located within 200 or 300 feet of each other. They were tested separately and showed a flow of 700 gallons a minute, or 1,000,000 a day. When the whole four were thrown on the system, it was found that the system was only augmented 1,000,000 gallons a day, showing conclusively that there was only 1,000,000 gallons of available water in that locality. Recently, four more wells were bored, about 600 feet apart with practically the same result. There is just so much water in the sand in a certain radius, and if you put one well close enough to another, and pump it strong enough, you will get very nearly as much water from one well as you will from two. Consequently, the city of Memphis in the last three years has put in a system of pumps which are run by electric motors in a pit in the ground, which permits wells to be located miles apart, the water being pumped from the well into the main at one operation under pressure.

A great many people from this country and some who have come all the way from Japan have seen this.

Mr. B. F. Stedman: This subject of water from underground flow is well worthy of close study. We put down ten wells, pumping them with direct connected pumps. They are six inch wells and are located fifty feet apart. With a six inch pump direct connected we can pump 100 gallons per minute. Within the last five years the flow from these wells has increased rather than decreased, the head being determined by the flow or head of the river. When the river is down, as it was a year ago to the lowest stage known in the history of the city of Dubuque, the wells were on a level with the river head. It takes about thirty-six hours for the wells to reach the same head as the river. When the river head increases, if it comes up to a flood stage of fifteen or twenty feet, our wells come up thirty-six hours afterwards. This shows that there is in this ground flow an outlet somewhere into the river which the river controls. We are at the present time installing, on the basis of what we have done with the six inch wells, a well eight feet in diameter and 98 feet deep, down to hard-pan. It is confidently believed that it will give us an absolutely steady flow of water. Although we have pumped from these different wells for six years the steady flow has not decreased; in fact, it is better today than it ever was, which is because, in the opinion of the speaker, there is a gravel pit around the wells.

Mr. E. E. Davis: The first artesian well the speaker ever saw was some twenty years ago at a little town in Virginia. It had a flow of 750 gallons a minute. The company built a water works and dug an artesian well about a quarter of a mile away from the spring, for the reason that the town would not allow use of the water from the spring and the water rose in that well, which was 600 feet deep, to within 20 feet of the surface. They built a reservoir of 200,000,000 gallons capacity, and when they pumped the reservoir full of water it nearly dried up the spring. The question was why it did not rise in the well as high as it was in the spring? When they were pumping water out of the well the spring went dry.

A paper mill company in Richmond dug a well 650 feet deep, and they could never get the water to rise higher than 50 feet below the surface of the ground. They found that the water stayed on a level with the water in the river.

MR. A. A. REIMER: That the wells mentioned by Mr. Stedman are better after six years' use is an interesting statement. To those of us who have handled gravel wells Mr. Stedman's statement indicates that he has not yet reached the limit of his wells, and that when he does he will find that they will run out pretty rapidly. In the case of the wells under the speaker's charge the limit has been reached and the wells have to be back-flushed every few years, the silting up process being fairly rapid. For a while the wells seemed to improve, the more they were pumped the better they got, until the limit of the wells was reached, then in a short time the pumpage from those wells ran off. Mr. Stedman will find in the course of time that the fine silt is responsible for a falling off in his wells. This silt is very fine material which works into the coarser material if the pumpage rate is high, and gradually builds a wall right around the well, maybe within a foot or possibly 25 feet away from the well. But Mr. Stedman is going to get that silting action in the course of time, and then the only relief is back-flushing.

MR. B. F. STEDMAN: When we first put the six inch wells down, we pumped them with a direct connected pump for several hours in order to take what sand would flow into the strainer out. The influx of sand afterwards stopped, and all the sand was pumped out before connecting the well with our pumps.

THE USE OF LIQUID CHLORINE FOR STERILIZING WATER

By John A. Kienle

In presenting this paper to the membership of your association the writer desires to acquaint you with a new development in the process of sterilizing water, which has only recently been reduced to commercial practice after years of experimenting on a laboratory-scale.

This process relates to the application of liquid chlorine to city water and sewage for sterilization and disinfection purposes.

Before going into the details of application and results obtained therefrom it may be advisable, in order to bring about a better understanding of the history of its development, to give some data about the product used.

Liquid Chlorine is the trade name for liquefied chlorine gas. The commercial process by which the gas is now generated almost exclusively is the electrolysis of brine, which under the influence of the electric current is split up into chlorine and sodium which reacts with water to form caustic soda.

The chlorine thus generated is subsequently dried, compressed and cooled until it liquefies. In the course of this process the gas is simultaneously relieved of all such impurities as water, carbon-dioxide, oxygen, air, etc., so that the final product represents the element chlorine in its most efficient form of about 99.5 to 99.9 per cent. purity.

Chlorine in this liquid state occupies only 1/400 of the space of the gas under the same temperature conditions and is placed into steel cylinders of about 80 pounds weight having a capacity of 100 to 110 pounds.

These units of about 180 pounds gross weight have been found to be the most convenient form for all practical purposes. The chlorine can be drawn off at will by opening the valve on top of the cylinder. It does not matter how much or how little is taken from the cylinder, liquid chlorine being the pure compressed gas

does not deteriorate or lose in efficiency by storing, as is the case with bleaching powder.

The industry of chlorine liquefaction is of very recent date in this country, the first liquefying plant having been started only seven years ago. Since then the industry and the introduction of its product into new fields of application have grown very rapidly and it is now used extensively in textile mills, for general bleaching purposes and by the chemical manufacturing industries in various processes such as detinning, etc., after having shown considerable advantages as to high efficiency, easier handling and higher economy than other and older methods of application.

Only after chlorine had thus been brought into a form which permitted convenient handling by the trade in general could it be considered feasible to conduct experiments with the idea of using its well-known bactericidal properties for water sterilization by direct application.

These experiments have been carried on by different scientists, the first to publish any results being Major C. R. Darnell, who in the fall of 1910 conducted laboratory tests with very good results bacteriologically, but the method employed, in the light of more recent data, did not seem entirely practical as he stated that "sixteen mixing chambers ten feet in diameter and two hundred feet long would be required" for New York City's daily supply.

Later experiments were conducted by D. D. Jackson of the New York Water Department at the Mount Prospect Laboratories and also at Cleveland, Ohio, which demonstrated the superior merits of liquid chlorine under efficient control. Members of the association may recall Dr. Jackson's reference to this product in his paper on "Chlorination at Cleveland" presented at the last convention. Throughout this time other and more satisfactory tests were being conducted by Dr. George Ornstein and practical experiments were made at the Western New York Water Company Plant at Niagara Falls, also at the filtration plants at Belmont, Philadelphia, and Wilmington, Delaware.

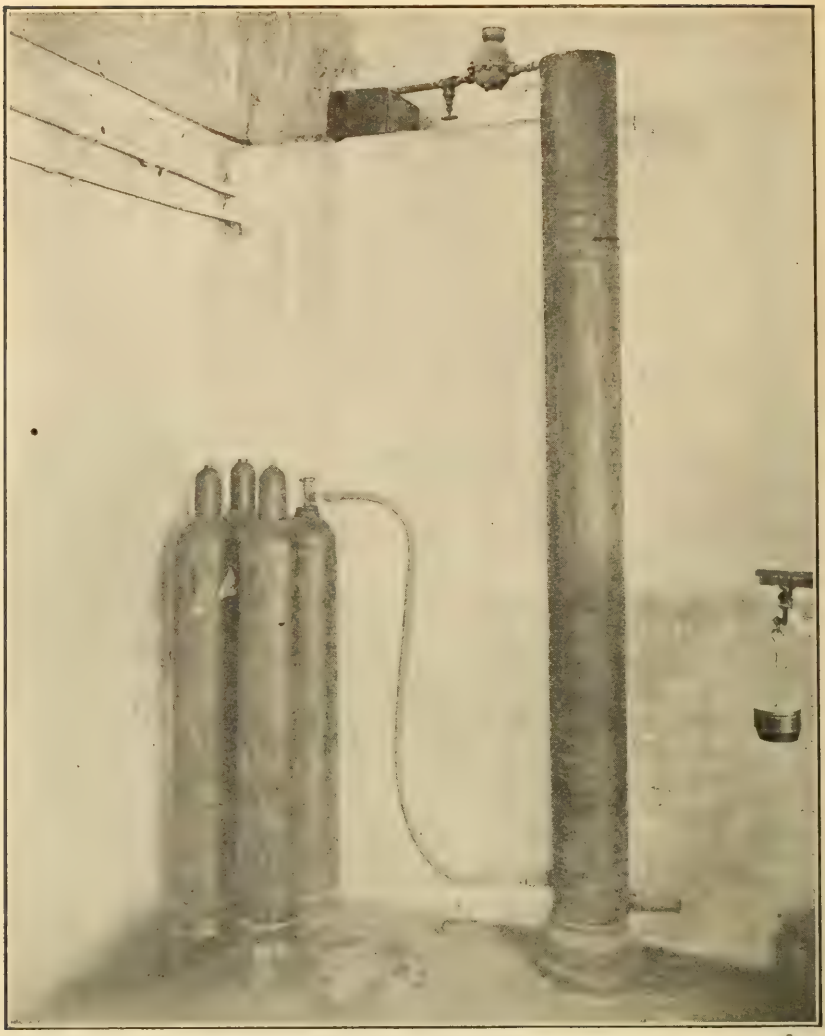
All of this experimental work demonstrated the advantageous features of the use of liquid chlorine and definitely determined its exceptional bactericidal properties, yet on the other hand the drawbacks and inefficiencies of the various methods of applying the chemical were forcibly impressed upon the minds of those who attempted its control. The difficulty arose in the development of a commercial and practical apparatus for efficiently regu-

lating the rate of flow of the chlorine gas. Most of the failures on this score were due to the strong corrosive effects of chlorine on all kinds of metals, wood, rubber, etc.

The majority of these when used in the presence of moisture were either totally destroyed or made inoperative in a very short space of time, seldom lasting more than seventy-two hours. Another and most important feature in connection with the experimental work was the development of an economical method of securing a proper absorption of the chlorine gas without the escape of any to the atmosphere and without loss of efficiency. That chlorine has a remarkable affinity for water is a well-known fact, it being possible to absorb in water at ordinary temperatures (60 degrees Fahrenheit) approximately two and one half volumes, equivalent to 8000 parts per million by weight. However, notwithstanding this, experience disclosed the fact that upon the liberation of the gas in an open body of water it quickly bubbled to the surface and escaped as free chlorine. The varying heads under which it was introduced also affected the rate of discharge of the gas.

The writer's experiments upon the use of this chemical were begun in December, 1912, and at first were rather discouraging. However, being enabled to profit by the experience of the Philadelphia authorities at Belmont filters and acting upon ideas advanced by Dr. Ornstein, the problems of absorption and back pressure were temporarily overcome by the installation of a piece of ordinary eight-inch cast iron pipe acting as an absorption tower. The cylinder of chlorine was directly connected to the bottom of this tower with lead service pipe as shown in the accompanying illustration. A minor quantity of water was introduced at the top of this tower through a $\frac{5}{8}$-inch meter and the effluent from the bottom regulated accordingly. This chlorinated water solution was then applied to the water to be treated after having been tested for its strength and the rate of treatment was determined by frequent readings of the $\frac{5}{8}$-inch meter.

The only valve used for controlling the rate of supply of chlorine gas was that on the chlorine cylinder which was fairly accurate as long as the temperature remained reasonably constant. Your attention at this point is called to the fact that the pressure inside of a chlorine cylinder varies with the atmospheric temperatures and is also affected by the rate of discharge since the expanding of the liquid chlorine to gaseous form results in cooling of the



EXPERIMENTAL CHLORINE APPARATUS
(Installed by Author)

liquid to the extent of freezing the valve outlet and with consequent reduction of internal pressures.

While the crude apparatus here shown accomplished desirable results bacteriologically, it is evident that such a method of application would not be commercially satisfactory and furthermore

the lead pipe and ferrule connections lasted but a short time. A balance weighted pressure reducing valve which had been connected to the cylinder also became inoperative after forty-eight hours' service.

These experiences finally resulted in the writer's recommendation to the water board to accept a proposition for the installation of an apparatus by a firm that agreed to demonstrate the efficiency of their controlling mechanism for a period of thirty days and to guarantee the apparatus against deterioration for one year from date of service.

This installation was completed on February 1, 1913, and since that time has been giving excellent satisfaction as may be seen from the accompanying tabulations. The results during the month of January were those obtained through the intermittent use of the iron pipe apparatus previously described, pending the installation of the permanent plant. Reference to the figures showing the bacterial count clearly indicates the effectiveness of the chlorine when used. More important, however, is the data showing the absolute elimination of B. coli communis when chlorine was being applied and its recurring presence immediately after treatment had been stopped, as was frequently the case in January owing to almost constant difficulty resulting from corrosion.

Attention is also called to the irregularities in the rate of flow of the chemical due to the temperature changes which, though small, affected the internal cylinder pressure on the gas.

CITY OF WILMINGTON, DEL. (Water Department)

DATE	TURBIDITY				ALKALINITY		BACTERIA PER CUBIC CENTIMETER										B. COLI-COMMUNIS*						Water Filtered	CHEMICALS	
																								Chlorine Gas	
Jan.	Raw	Pre. Filt.	Applied	Combined Effluent	Raw	Combined Effluent	Raw	Pre. Filt.	Applied	A	B	C	D	E	F	Combined Effluent After Treatment	High Service Tap	Low Service Tap	Raw	Pre. Filt.	Applied	Combined Effluent After Treatment	High Service Tap	Low Service Tap		Pounds Daily	Grs. per Gal.
1	70	70	30	0	18	25	52,100	42,800	28,200	108	880	432	1320	352	314	260	530	560	5/5	5/5	5/5	1/5	0/5	0/5	9,730,000	20.8	0.0146
2	35	35	25	0	24	24	46,000	30,900	21,600	246	430	294	1340	306	350	22	32	624	5/5	5/5	5/5	0/5	0/5	0/5	9,960,000	20.8	0.0146
3	30	20	25	0	27	22	63,700	42,000	30,600	1220	334	292	752	286	242	65	72	402	5/5	5/5	5/5	0/5	0/5	0/5	10,400,000	20.8	0.0146
4	160	120	50	0	20	22	66,700	61,900	32,900	900	304	286	758	244	262	72	42	368	5/5	5/5	5/5	0/5	0/5	0/5	10,050,000	20.8	0.0146
5	...	60	70	0	...	23	53,400	35,700	28,900	1300	390	396	992	550	244	116*	78	446	5/5	5/5	5/5	0/5	0/5	0/5	10,090,000	20.8	0.0146
6	60	50	60	0	29	23	42,400	40,200	34,000	2020	328	442	1204	576	402	168*	170	524	5/5	5/5	5/5	1/5	0/5	1/5	10,220,000	10.4	0.00729
7	35	30	35	0	29	24	47,900	36,300	28,700	2180	386	316	896	530	†	152*	398	364	5/5	5/5	5/5	1/5	0/5	0/5	9,730,000	10.4	0.00729
8	40	30	35	0	32	24	57,700	44,500	32,100	1580	576	820	†	2540	2600	171*	2860	498	5/5	5/5	5/5	2/5	1/5	0/5	9,170,000	10.4	0.00729
9	40	35	35	0	30	25	53,800	46,100	30,900	920	330	3080	2120	1700	1360	668*	3260	496	5/5	5/5	5/5	3/5	0/5	0/5	8,610,000	20.8	0.0146
10	100	70	50	0	29	26	48,300	37,100	29,900	680	820	2160	1820	640	1140	233*	2380	256	5/5	5/5	5/5	0/5	0/5	0/5	10,180,000	20.8	0.0146
11	50	40	40	0	32	27	53,900	34,600	31,300	342	1020	1180	2180	1740	1110	51	2300	384	5/5	5/5	5/5	0/5	0/5	0/5	10,480,000	20.8	0.0146
12	...	30	35	0	...	28	52,800	41,200	30,200	480	542	1100	1360	660	960	56	64	350	5/5	5/5	5/5	0/5	0/5	0/5	11,650,000	25.0	0.0146
13	30	25	30	0	33	30	49,200	39,000	32,100	340	560	1080	1020	840	1060	83	128	498	5/5	5/5	5/5	0/5	0/5	0/5	10,600,000	25.0	0.0146
14	35	30	30	0	32	30	29,500	22,100	20,800	292	524	740	1070	780	2100	76	130	462	5/5	5/5	5/5	0/5	0/5	0/5	10,740,000	24.0	0.0156
15	30	25	25	0	31	30	22,300	14,100	12,500	620	424	540	1680	500	1380	80	5120	414	5/5	5/5	5/5	0/5	0/5	0/5	10,580,000	24.0	0.0158
16	25	20	25	0	33	30	23,500	14,400	12,900	1800	422	346	1320	462	740	72	4320	524	5/5	5/5	5/5	0/5	0/5	0/5	11,290,000	24.0	0.0148
17	40	40	30	0	32	32	35,900	24,100	21,600	680	†	1100	1020	342	950	74	5180	384	5/5	5/5	5/5	1/5	0/5	1/5	10,990,000	24.0	0.0152
18	120	80	40	0	30	31	44,500	33,600	30,400	840	1620	1280	740	1080	660	167*	1500	520	5/5	5/5	5/5	0/5	1/5	0/5	11,890,000	25.0	0.0147
19	...	40	40	0	...	31	49,900	34,700	33,200	‡	1540	1440	980	960	440	96*	98	274	5/5	5/5	5/5	1/5	0/5	0/5	11,390,000	25.0	0.0153
20	35	30	30	0	32	30	44,300	27,400	22,300	580	1520	1000	640	510	262	105*	5760	322	5/5	5/5	5/5	0/5	0/5	0/5	12,300,000	18.0	0.0102
21	30	25	30	0	31	31	14,900	11,500	10,300	352	‡	520	366	540	224	459*	4062	432	5/5	5/5	5/5	3/5	2/5	0/5	11,440,000	24.0	0.0146
22	35	30	35	0	33	31	33,500	23,100	16,900	276	580	540	322	424	182	30	38	390	5/5	5/5	5/5	0/5	0/5	0/5	12,270,000	25.0	0.0142
23	30	25	25	0	33	32	21,100	16,300	10,900	198	620	‡	192	368	132	53	55	508	5/5	5/5	5/5	0/5	0/5	0/5	11,140,000	25.0	0.0157
24	35	25	30	0	33	33	26,400	17,600	15,500	208	436	292	‡	188	154	37	84	324	5/5	5/5	5/5	0/5	0/5	0/5	11,660,000	18.0	0.0107
25	25	20	20	0	33	33	31,700	21,300	16,500	244	408	536	404	294	126	39	94	580	5/5	5/5	5/5	0/5	0/5	0/5	11,440,000	18.0	0.0125
26	...	15	20	0	...	33	30,100	18,600	18,900	130	198	342	218	154	124	352*	174	410	5/5	5/5	5/5	1/5	1/5	2/5	9,980,000	. . .	. . . . .
27	20	15	20	0	32	32	21,300	15,600	14,500	152	196	312	166	190	152	244*	328	412	5/5	5/5	5/5	0/5	0/5	1/5	7,880,000	17.0	0.0152
28	40	30	25	0	29	31	28,100	17,700	10,400	146	184	156	194	192	86	25	32	234	5/5	5/5	5/5	0/5	1/5	1/5	10,420,000	28.0	0.0188
29	35	25	25	0	29	31	13,700	9,200	7,300	112	136	140	186	122	‡	26	30	266	5/5	5/5	5/5	0/5	0/5	0/5	11,090,000	24.0	0.0155
30	25	15	20	0	34	32	10,800	8,600	8,800	134	132	152	144	160	94	29	40	260	5/5	5/5	5/5	0/5	0/5	0/5	11,540,000	24.0	0.0145
31	20	15	20	0	34	32	11,500	7,700	6,400	120	104	124	140	82	164	194*	90	432	5/5	5/5	5/5	0/5	1/5	0/5	10,400,000	18.0	0.0120

Chlorine apparatus not working during month of January. Author's experimental apparatus was under test. Five samples of each water analyzed for B. Coli.

†Washed. ‡Raked.

CITY OF WILMINGTON, DEL. (Water Department)

DATE	TURBIDITY				ALKALINITY		BACTERIA PER CUBIC CENTIMETER										B. COLI-COMMUNIS						Water Filtered	CHEMICALS	
																								Chlorine Gas	
Feb.	Raw	Pre. Filt.	Applied	Combined Effluent	Raw	Combined Effluent	Raw	Pre. Filt.	Applied	A	B	C	D	E	F	Combined Effluent After Treatmen	High Service Tap	Low Service Tap	Raw	Pre. Filt	Applied	Combined Effluent After Treatment	High Service Tap	Low Service Tap		Pounds Daily	Grs. per Gal.
1...	20	15	15	0	34	31	11,700	8,700	7,300	162	112	184	152	148	120	210*	168	292	5/5	5/5	5/5	1/5	0/5	0/5	9,640,000	9.0	0·0058
2...	...	15	15	0	...	33	13,200	9,300	8,500	136	84	102	110	134	114	35	44	206	5/5	5/5	4/5	0/5	0/5	0/5	9,590,000	18.0	0.0130
3...	15	12	15	0	34	33	14,500	11,200	7,200	212	80	114	128	†	144	54	104	236	5/5	5/5	4/5	0/5	0/5	0/5	9,400,000	13.0	0.0096
4...	25	20	20	0	29	33	17,100	12,900	9,100	112	102	108	120	206	142	46	62	210	5/5	5/5	5/5	0/5	0/5	0/5	10,890,000	18.0	0.0115
5...	25	20	20	0	29	33	22,600	17,100	9,500	142	86	106	96	134	102	19	...	278	5/5	5/5	5/5	0/5	0/5	0/5	10,870,000	18.0	0.0115
6...	20	15	15	0	29	31	22,500	16,900	11,600	136	118	102	120	182	156	22	36	208	5/5	5/5	5/5	0/5	0/5	0/5	11,260,000	18.0	0.0111
7...	20	15	15	0	31	30	15,600	13,200	9,200	156	112	132	104	292	160	21	50	228	5/5	5/5	4/5	1/5	0/5	0/5	11,620,000	18 0	0.0108
8...	20	20	15	0	34	31	18,200	14,300	12,400	132	140	164	102	272	104	28	42	276	4/5	5/5	5/5	0/5	0/5	0/5	11,290,000	18.0	0.0111
9...	...	25	20	0	...	33	23,600	14,100	15,500	204	196	166	184	288	232	27	38	312	5/5	5/5	4/5	0/5	0/5	0/5	10,410,000	19.0	0.0127
10...	15	15	12	0	32	33	26,400	21,900	15,900	122	118	84	208	372	212	30	42	220	4/5	5/5	5/5	0/5	0/5	0/5	9,630,000	18.0	0.0131
11...	15	10	15	0	34	34	27,100	21,700	14,500	192	122	138	216	392	220	18	52	212	4/5	5/5	5/5	0/5	0/5	0/5	10,130,000	18.0	0.0124
12...	15	15	15	0	33	33	29,600	25,300	18,400	†	184	172	230	264	224	23	24	232	5/5	5/5	5/5	0/5	0/5	0/5	9,540,000	18.0	0.0132
13...	15	15	15	0	33	33	28,100	20,400	18,700	250	196	160	248	268	232	20	26	236	5/5	5/5	4/5	0/5	0/5	0/5	10,850,000	18.0	0.0116
14. .	20	15	15	0	35	34	25,100	21,300	15,100	376	†	132	201	308	228	16	18	196	5/5	4/5	4/5	0/5	0/5	0/5	10,530,000	18.0	0.0119
15...	20	15	15	0	37	33	31,400	27,900	21,900	416	1840	†	248	336	152	17	20	218	5/5	5/5	3/5	0/5	0/5	0/5	11,170,000	18.0	0.0112
16...	...	20	15	0	...	34	39,300	28,500	28,700	720	2480	1060	344	360	282	19	22	216	5/5	5/5	5/5	0/5	0/5	0/5	11,230,000	18.0	0.0112
17...	15	15	15	0	35	35	33,800	29,500	20,400	560	2020	1380	†	190	260	21	24	200	5/5	5/5	4/5	0/5	0/5	0/5	10,730,000	18 0	0 0117
18...	15	15	15	0	33	35	36,800	27,100	30,600	340	1460	840	1120	†	208	23	26	228	5/5	5/5	4/5	0/5	0/5	0/5	10,430,000	18.0	0.0121
19...	15	15	15	0	32	33	36,300	32,700	26,000	272	960	680	860	1380	820	18	24	236	5/5	5/5	5/5	0/5	0/5	0/5	10,660,000	18.0	0.0118
20...	20	20	15	0	35	34	35,400	26,500	19,600	320	480	560	590	940	600	26	32	216	5/5	4/5	4/5	0/5	0/5	0/5	11,350,000	18.0	0.0111
21...	20	20	20	0	36	34	26,700	20,200	18,900	240	380	480	320	560	300	25	28	232	5/5	5/5	4/5	0/5	0/5	0/5	10,720,000	16 5	0.0107
22...	...	20	20	0	...	35	47,700	41,500	32,500	362	300	346	322	480	276	23	30	220	5/5	5/5	5/5	0/5	0/5	0/5	10,470,000	16.0	0.0106
23...	...	20	20	0	...	35	44,600	36,100	27,000	144	262	252	200	220	302	22	34	224	5/5	5/5	5/5	0/5	0/5	0/5	10,820,000	16.0	0 0103
24...	30	20	20	0	35	34	49,500	31,300	28,100	420	302	224	210	340	360	200*	220	310	5/5	5/5	5/5	0/5	0/5	0/5	10,850,000	8.0	0 0051
25...	35	30	25	0	30	32	30,500	21,000	17,400	288	264	380	380	320	320	14	18	256	5/5	5/5	5/5	0/5	1/5	0 5	10,110,000	19.0	0 0131
26...	20	20	20	0	32	32	25,100	14,300	12,600	204	176	252	202	380	1280	18	84	224	5/5	4/5	5/5	0/5	1/5	0/5	10,990,000	18.0	0 0115
27...	20	20	20	0	35	33	23,500	17,300	13,600	280	170	232	204	240	1140	25	28	240	5/5	3/5	5/5	0/5	0/5	0/5	11,890,000	19.5	0.0114
28...	250	120	50	0	28	32	43,600	37,500	28,600	224	172	244	256	360	1120	26	32	276	5/5	5/5	5/5	0/5	0/5	0/5	11,360,000	15.5	0.0095

*Chlorine apparatus out for adjustment. Installation of improved apparatus completed February 1st. Treatment regular thereafter.

‡Raked.

WATER DEPARTMENT WILMINGTON, DEL.

1913- AVERAGE WEEKLY RESULTS FROM LIQUID CHLORINE TREATMENT-1913.

DATE	TURBIDITY				BACTERIA PER CUBIC CENTIMETER								PRESUMPTIVE TEST B. COLI COMMUNIS								
WEEK ENDING	RAW WATER	PRE FILTER	APPLIED WATER	COMBINED EFFLUENT	RAW WATER	PRE FILTER	APPLIED WATER	FILTER BED A	FILTER BED F	COMB EFFL'NT TREATED	HIGH SERVICE TAP	LOW SERVICE TAP	RAW WATER	PRE FILTER	APPLIED WATER	COMBINED EFF TREATED	HIGH SERVICE TAP	LOW SERVICE TAP	WATER FILTERED DAILY AVERAGE	POUNDS OF CHLORIN DAILY
MAR 8	23	26	37	0	49200	36000	23500	206	264	50	52	178	35/35	34/35	35/35	0/35	0/35	0/35	8984300	14.8
MAR 15	69	50	30	0	49400	30500	22000	183	234	24	29	148	35/35	34/35	33/35	0/35	1/35	0/35	10205700	18.5
MAR 22	98	70	50	0	45400	28700	14100	150	172	21	27	120	35/35	35/35	35/35	2/35	1/35	0/35	10820000	17.4
MAR 29	140	100	61	0	43200	23000	12800	244	113	23	29	97	35/35	35/35	35/35	3/35	3/35	1/35	10275700	19.3
APRIL 5	36	47	42	0	23600	17200	11200	141	73	15	24	82	35/35	35/35	35/35	1/35	4/35	2/35	10960000	18.8
ARRIL 12	45	45	45	0	14900	11100	5400	53	50	15	18	65	34/35	33/35	33/35	0/35	0/35	4/35	11137100	18.3
APRIL 19	155	130	54	0	20500	16800	10000	31	27	10	14	96	30/30	34/35	35/35	1/35	0/35	1/35	10727100	16.5
APRIL 26	22	17	27	0	13300	9100	5400	27	25	11	12	195	9/10	23/25	23/25	0/25	0/25	0/25	11462900	15.5
MAY 3	130	21	29	0	18600	9800	6800	27	29	12	14	744	35/35	33/35	35/35	1/35	0/35	0/35	10817100	16.2
MAY 10	20	16	20	0	3600	2300	2300	23	26	10	8	204	30/30	33/35	33/35	0/35	1/35	0/35	12344300	18.2
MAY 17	17	16	14	0	8500	4200	2000	73	86	6	9	58	34/35	35/35	28/35	0/35	0/35	0/35	11932900	15.4
MAY 24	605	221	36	0	19000	9100	4500	34	414	10	7	75	30/30	30/30	35/35	0/35	0/35	2/35	10892900	15.4
MAY 31	69	105	58	0	21600	18900	7600	135	147	16	17	73	30/30	35/35	35/35	0/35	0/35	0/35	10611400	17.3
																			141141400	221.6

AVERAGE 1.56

WATER DEPARTMENT WILMINGTON, DEL.

1912-AVERAGE WEEKLY RESULTS FROM HYPO-CHLORITE TREATMENT-1912

DATE	TURBIDITY				BACTERIA PER CUBIC CENTIMETER								PRESUMPTIVE TEST B COLI COMMUNIS						WATER FILTERED	POUNDS OF HYPO
WEEK ENDING	RAW WATER	PRE FILTER	APPLIED WATER	COMBINED EFFLUENT	RAW WATER	PRE FILTER	APPLIED WATER	FILTER BED A	FILTER BED F	COMB EFFL'NT TREATED	HIGH SERVICE TAP	LOW SERVICE TAP	RAW	PRE FILTER	APPLIED	COMBINED EFFLUENT	HIGH SERVICE TAP	LOW SERVICE TAP	DAILY AVERAGE	DAILY
MAR. 2	130	90	114	30	640000	633000	600000	9100	8745	420	735	1900	6/6	6/6	6/6	4/6	0/6	1/6	8620000	195
MAR. 9	75	30	24	5	715000	483000	406000	3900	4800	61	71	102	6/6	6/6	6/6	1/6	0/6	0/6	11607000	200
MAR. 16	342	146	183	9	1266000	788000	383000	3000	2850	50	810	3000	6/6	6/6	6/6	0/6	0/6	0/6	11063000	130
MAR. 23	76	52	123	31	1066000	600000	506000	2000	1900	60	440	50000	6/6	6/6	6/6	0/6	0/6	0/6	10613000	150
MAR 30	166	80	50	4	833000	566000	400000	1100	1030	500	1700	26600	6/6	6/6	6/6	0/6	0/6	0/6	11217000	110
APRIL 6	300	132	145	11	883000	716000	533000	680	760	90	1260	3960	6/6	6/6	6/6	0/6	0/6	0/6	11150000	85
APRIL 13	28	15	64	10	936000	728000	556000	1300	1480	70	1720	7000	5/5	5/5	5/5	0/5	0/5	0/5	10944000	75
APRIL 20	20	9	23	2	610000	584000	126000	240	310	56	1000	2430	5/5	5/5	5/5	0/5	0/5	0/5	10464000	75
APRIL 27	11	5	20	1	390000	136500	60000	116	230	30	174	260	6/6	6/6	6/6	1/6	1/6	2/6	9994000	70
																			95672000	1090

AVERAGE 11.38

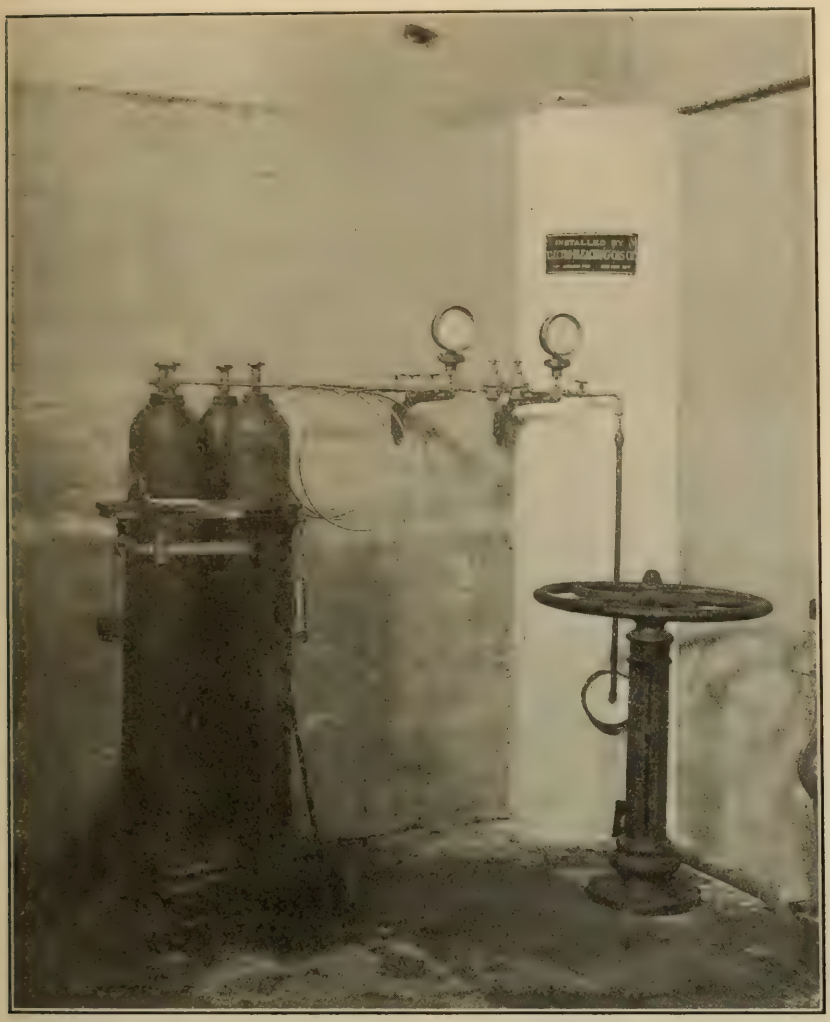
For the purpose of comparison a complete tabulation of the daily results for the month of February is given which clearly indicates the regularity of flow given by the improved apparatus and also the exceptional bacteriological results obtained. It is particularly interesting to note that on the 24th of the month when the apparatus was shut down a few hours for some minor alterations the bacterial count immediately increased from an average of 20 to 200 per c.c., the tap water in the city also being affected in like proportion.

As no attempt was made to regulate the flow of gas precisely in direct proportion to the rate of filtration the figures in the last column (giving grains per gallon) vary slightly. It had been predetermined to set the valve controlling the discharge of gas at a position to deliver $\frac{3}{4}$ of a pound per hour equivalent to $1\frac{1}{2}$ pounds per 1,000,000 gallons of water upon a 12,000,000 gallon daily basis, which was the maximum daily rate of filtration. As this amount was known to be sufficient to eliminate B. coli no further attempt was made to regulate the rates of flow of gas which with the varying filter rate accounts for the slight change in grains per gallon.

The city at that time was purchasing liquid chlorine in small quantities at the rate of 10 cents per pound f.o.b. Niagara Falls, while the freight charges and hauling to the plant added approximately $\frac{3}{4}$ cent per pound. As four 100-pound cylinders were connected to the apparatus and the daily quantity consumed was but 18 pounds the only labor involved in operation was that of changing the tanks once in every three or four weeks, a task requiring about fifteen minutes of the filter attendants' time. It is, therefore, evident that the cost of the treatment is very low, not exceeding in this instance $16\frac{1}{2}$ cents per 1,000,000 gallons of water treated.

The controlling apparatus installed at Wilmington, as shown in the accompanying illustration, consists of a series of pipe coils for connecting the cylinders of gas to a manifold upon which is placed pressure gage with a specially prepared diaphragm for determining the initial pressures and indicating when the cylinders are exhausted. Beyond this gage two pressure regulating devices of special and unique design are installed, the first being used primarily for reducing the initial cylinder pressure and maintaining it at a predetermined maximum, while the second is used for regulating this reduced pressure through a range sufficient to give the desired discharge of gas.

To a branch outlet on the line between the last controlling valve and the discharge orifice there is attached a low pressure chlorine



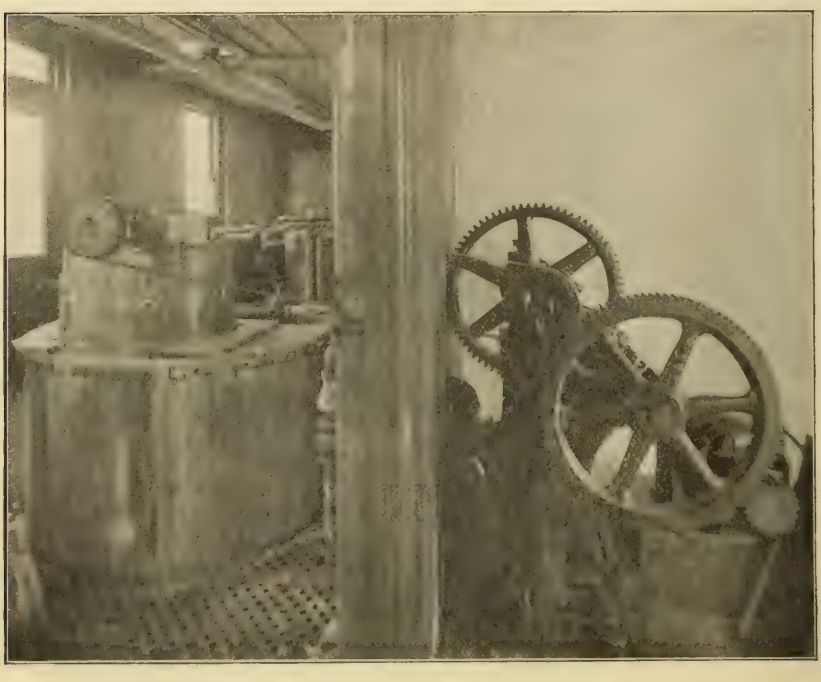
LIQUID CHLORINE GAS APPARATUS

gage which is calibrated empirically to indicate the rate of flow of gas in pounds per hour. After passing the discharge outlet the gas is conducted by composition hard rubber tubing to an absorption tower designed to secure a thorough admixture of the chlorine in a minor quantity of water without the escape of any gas to the atmosphere. This tower was of a German American stoneware composition which resists the chemical action of the gas during the

absorption process. Though encased in a plaster covering, as shown, this tower is open to atmospheric pressure at the top and any failure to secure an absolute absorption is indicated and known immediately by the presence of free chlorine in the atmosphere. The chlorinated water solution flows by gravity from the bottom of the tower to the 30-inch pipe at a point just prior to its discharge into the clear water reservoir.

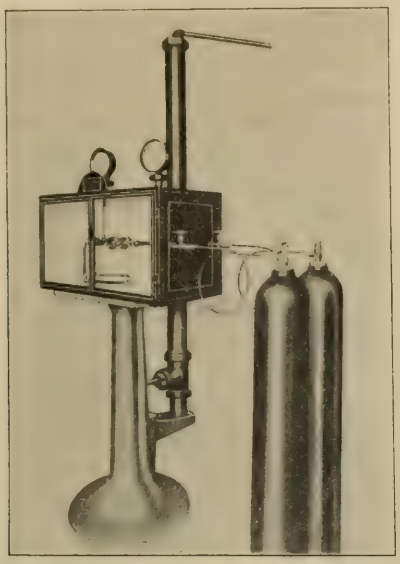
More recent designs of the apparatus are self contained with the working parts encased and the absorption tower bracketed at the rear of the pedestal. Where the supply to be treated passes through a Venturi tube an automatic controlling device can be installed in the case which will regulate the supply of chlorine in any desired proportion to the flow of water.

As matter of considerable interest and for the purpose of comparison the bacteriological results obtained from the emergency use of hypochlorite of lime during the corresponding period of the previous year at the Wilmington filter plant are also given in the tabu-



Emergency Hypo-chlorite Apparatus

lated statements. Attention is called to the fact that the treatment plant was hurriedly installed and operated in a manner not conducive to obtaining the most satisfactory and economical results. This emergency plant (see Annual Report Water Dep't, 1911–12) consisted of a circular iron solution tank 3 feet 6 inches in diameter and 3 feet deep, while for a mechanical hypo mixing chamber an ordinary domestic laundry machine was purchased and connected by a belt to the crank disc of a triplex power pump which was used



IMPROVED TYPE OF LIQUID CHLORINE APPARATUS

for pumping the hypo solution to filter plant. As there was no alternate solution tank a continuous flow was necessary and the powder was, therefore, dumped into the mixing chamber in small quantities at regular intervals.

Despite the crudeness of installation care was taken to insure the best reliability of operation possible under the circumstances by supplying sufficient labor and supervision, and the detailed data show that this result was secured with a fair degree of accuracy.

Analysis of the tabulation given shows that the average weekly count in the water after treatment with hypochlorite of lime, ranges from 30 to 500 bacteria per c.c., notwithstanding the use of from 7 to 22½ or an average of 11½ pounds of hypo per 1,000,000 gallons of

water treated. It is also evident that samples of the water showed the presence of B. Coli communis during weeks when the maximum quantity was being used. The writer recalls that tastes and odors predominated when more than 10 pounds of powder per 1,000,000 gallons were used.

By comparison with the results obtained from the use of liquid chlorine it will be seen that the count ranged from 6 to 50 bacteria per c.c. during the same but longer period of the following year. Also that the presence of B. coli was indicated in only 8 out of 445 samples of water tested. These results were obtained by the use of from $1\frac{1}{3}$ to $1\frac{87}{100}$ or an average of $1\frac{56}{100}$ pounds of liquid chlorine per 1,000,000 gallons. As the cost of hypochlorite delivered at the plant was approximately $1\frac{1}{2}$ cents per pound it is, therefore, evident that there was a considerable direct saving in the cost of the chemical by the use of liquid chlorine exclusive of the saving in labor and power required for mixing and handling the hypo.

Attention is called to the exceptionally abnormal increase of bacteria in the city tap water following the treatment with hypochlorite, which increase did not prevail with the use of liquid chlorine. It should be noted that the portion of the treated water supplying the low service system is stored openly for a period of several days prior to delivery and a slight increase would naturally be expected. The writer is not prepared at this time to assert that liquid chlorine is more effective than hypochlorite in the prevention of so-called "after growths." The writer does believe, however, that further studies will prove this to be a fact as the evidence given points in that direction. The assumption that liquid chlorine due to its increased efficiency is more active in the reduction of spore-forming bacteria is, at least, certainly warranted.

The experiments conducted at the Belmont filters in Philadelphia demonstrated to the satisfaction of the water bureau officials the economic and aesthetic advantages of the use of liquid chlorine as a sterilizing agent. At this plant attempts made by the officials in charge to control the flow of gas with ordinary types of valves proved unsatisfactory. Later the chlorine cylinders were enclosed in an asbestos lined metal box which was heated in order to maintain a more even temperature around the cylinders with a consequent regularity of internal pressures. The gas flow was then controlled by adjustment of the cylinder valves, the quantity discharged being checked every three hours by the use of platform scales.

As the gas was delivered *direct* to the water in the effluent gate house well and the level therein varied with the fluctuating height of water in the adjoining reservoir from 6 to 14 feet (approximately), there were numerous periods when a portion of the chlorine bubbled through and escaped to the atmosphere. The bacteriological results, however, were exceptionally good, the count in the treated water ranging from 4 to 10 bacteria per c.c. with negative tests for B. coli in 1 c.c. and 10 c.c. samples.

These results were secured with the use of only 1 pound of chlorine per 1,000,000 gallons of water which is indicative of the nominal cost of treatment.

At the Western New York Water Company's plant at Niagara Falls, N. Y., experiments with the use of liquid chlorine were begun in November, 1912, under the supervision of Dr. G. Ornstein, who acknowledges the valuable assistance tendered by principal assistant engineer of the plant, Mr. F. H. Huy.

Though the bacteriological results obtained from its use were not available in tabulated form at the time of the preparation of this paper the writer was reliably informed that they had been perfectly satisfactory. Economy of operation has also been effected, as advices from the plant indicate that the use of $\frac{1}{2}$ pound of liquid chlorine per 1,000,000 gallons superseded the prior use of 4 pounds of chloride of lime. In fact, during one period of the experimental treatment covering one week's operation good results were obtained with the use of $\frac{1}{6}$ of a pound of chlorine per 1,000,000 gallons.

The labor cost for mixing hypo solution was eliminated and prior to the use of liquid chlorine 100 per cent more sulphate of alumina was used. Irregularities in the original hypo treatment were also overcome by the prevention of the clogging of the pipes conveying the sterilizing agent to the water supply.

The officials in charge of this plant, as well as the chief engineer of the American Pipe and Construction Company, its owners, state that they are particularly well pleased with this new method of chlorination.

It is deemed advisable to note that the Niagara apparatus is not of the type which may be termed "gas controlled." Essentially it consists of gas cylinders, cylinder supply valves, an absorption tower, storage tank and orifice box. No attempt is made to measure or indicate direct the rate of flow of gas. The discharge of gas is controlled only by a series of chlorine cylinder valves prior to passage to the absorption tower. The flow of chlorine water, after

its strength has been determined by analysis, is regulated by an orifice box of a design with which the writer is not familiar.

Notwithstanding the lack of indicating devices the method of treatment has conclusively shown the merits of liquid chlorine for sterilizing purposes.

At Somersworth, New Hampshire, equally satisfactory results have been obtained though at somewhat increased cost due principally to the lower daily consumption and organic matter in the water. The use of gas at this plant is at the rate of $\frac{1}{3}$ of a pound per hour which is slightly more than actually required. This excess quantity is accounted for by the difficulty in maintaining a very low pressure on an extremely fine orifice required for such small velocities, a feature which has been overcome in more recent designs of apparatus.

In the writer's opinion the method of treatment described has many points of superiority over the use of hypochlorites. Briefly these may be summarized as follows:

1. Economy in cost of installation: As the apparatus is very compact requiring but a limited floor space it can be conveniently set up in any existing building. Storage space required reduced 300 to 500 per cent due to concentrated form in which chemical is shipped.

2. Labor and power costs in operation practically eliminated: No mixing and agitating of chemical required. Decreased bulk to be handled.

3. Simplicity in regulation of quantity of chlorine applied: No tests required to determine available chlorine in solution. No mineral salts introduced and consequently no difficulties in clogging of orifice boxes and chemical solution pipes with resulting unreliability of treatment.

4. Uniform strength of chemical with increased efficiency and activity: Liquid chlorine is $99\frac{9}{10}$ per cent pure and is not subject to deterioration from storage. More active particularly in cold weather with efficiency stated at 1 pound to $7\frac{1}{2}$ or 10 pounds of chloride of lime.

5. Disagreeable tastes and odors in treated water eliminated, notwithstanding the addition of 8 pounds of liquid chlorine per 1,000,000 gallons, which is considerably more than experience has shown is actually required for sterilization purposes. No residual chlorine is left in water.

6. No provision required for sludge disposal and elimination of corrosive influences of flying lime dusts.

DISCUSSION

Mr. D. D. Jackson: The speaker has been experimenting for over a year with liquid chlorine and has duplicated in a way all the results that have been obtained by Mr. Kienle. There is no question as to the statement which he has made regarding its increased activity, particularly at low temperature, the smaller amount necessary to be used and other points which he has brought out. Installations of hypochlorite of lime have been very troublesome in many cities. In the results which were obtained at Cleveland with chlorination the water was occasionally overdosed, causing a great deal of taste and odor; and it was from that period, which was about a year ago, that experiments were begun with liquid chlorine. The results which we have obtained have been chiefly upon the Brooklyn water supply where we installed a plant which was operated for treating 40,000,000 gallons. The apparatus used was entirely different in design from that described by Mr. Kienle, the main difference being that the chlorine is fed by weight instead of by volume. Cylinders are supported on balanced beams, and the delivery of the chlorine through the orifice is regulated by this balance beam which moves up and down and regulates by weight the exact amount of the chlorine used. This delivery by weight is brought about by a friction wheel which moves back and forth so that the amount is increased or diminished by the rapidity of the revolutions of this wheel. On the other side of the wheel another wheel regulates against the flow from the water itself, so that any motion which may be taken from the pump, from the Venturi or from float valve, may be transmitted to one side of the friction wheel, thus regulating the amount of chlorine by means of the flow of the water. On the other side of the friction wheel is a wheel which regulates the exact amount of chlorine which it is desirable to use. The apparatus, delivering as it does by weight, overcomes the effect of varying densities; the varying densities naturally being brought about by changes in temperature. The reduction in the temperature of the cylinder is very marked, particularly as the chlorine gets to the bottom of the cylinder, because all the heat which is necessary to gasify the chlorine must be taken from the cylinder itself. By weight delivery the variations in effects of changes in temperature and density are obviated.

The speaker believes that there is no question but what liquid

chlorine is the finest product for the sterilization of water, and that it will be the chief means adopted for sterilizing water in the future, and will have a marked bearing upon the purification installations which we will install both for water and for sewerage, because of its cheapness, and because we possess now the means of exactly regulating its flow automatically so that it requires practically no attention whatever, the flow from one cylinder to the second cylinder proceeding without any interval between. At any time during sterilization, when the first cylinder becomes emptied, it is automatically replaced. The machine in this case is in duplicate, and, as before stated, feeds entirely by weight.

To accomplish this on a practical and commercial scale the device is made to embody the following features:

1. Commercial chlorine stored in the liquid state in a steel flask, which contains about 100 pounds of the chlorine, is suspended from a scale beam, mounted on hardened steel knife edges, and capable of very accurate weighing. When so mounted, and the flask connectedby hard rubber tubing to the controlling valve of the machine, the gas is automatically fed, at the proper rate, into the water or sewage to be treated.

2. The device may be easily and quickly adjusted so that any desired weight of gas per million gallons of water or sewage will be fed, and this ratio will be maintained, the machine automatically adjusting itself to the varied flow.

3. In order that there may be no interruption in the feed when a storage flask becomes exhausted of its supply of gas, the machine is made in duplicate. That is to say, it is provided with two scale beams, from each of which a storage flask is suspended. One is held in reserve while the other is in operation. At the instant when number one becomes exhausted of its supply, number two is automatically thrown into action, so as to cause no stoppage in the treatment.

The empty flask may then, at the convenience of the attendant, be replaced by a filled one which will remain in reserve until it is in turn automatically thrown into operation.

4. The control valve which regulates the supply of gas is operated, through proper mechanism, by the scale beam.

The feed is, therefore, dependent upon the loss of weight of gas, and is altogether independent of the pressure of the gas. In other words, the rate of flow will be the same whether the pressure in the flask is high or low. This is a vital point, because the pressure in

the flask is subject to a wide variation, depending not only upon the temperature of the atmosphere, but also upon the rate at which the gas is drawn from the flask. It is because of this variation in pressure, and in temperature as well, that a reducing valve control is unsatisfactory, and in this machine no pressure reducing valve is used.

5. The variation in the rate of feed to correspond to fluctuations in the flow of water or sewage is controlled from the pumping engines, the rate being in proportion to the number of strokes per minute and the number of pumps in operation. Where the supply is passed through a Venturi meter, this latter may be utilized in place of the pumps for controlling the rate. In cases where the water or sewage to be treated spills over a weir, the machine is regulated from a float.

The above will give a general idea of the scope of the apparatus. One machine will successfully treat any amount, from one million to fifty million gallons of water in twenty-four hours. Where a greater quantity is to be treated it is best to install two or more machines. Since sewage will require considerably more of the gas than is necessary for the treatment of water supply, the maximum amount of sewage which can be handled by one machine is considerably less.

The bacteriological tests show that all B. coli are absolutely eliminated and water rendered perfectly safe for drinking purposes by amounts of chlorine far below the point where taste or odor is liable to develop. The machine prevents any possibility of overdosing or underdosing by its perfect automatic regulation.

The weight of chlorine used is about one-ninth the weight of hypochlorite of lime necessary to sterilize and the sterilization is more definite and permanent.

Mr. Edgar M. Hoopes: The speaker wishes to supplement the remarks of Mr. Kienle and Dr. Jackson with some additional information regarding the use of liquid chlorine as a substitute for copper sulphate in the treatment of algae. We have in Wilmington a 45,000,000 gallon filtered water storage reservoir which is open to the air and sunlight. During the summer months, particularly June and July, we are troubled with microscopic organisms in the water stored in this reservoir, these being particularly algae growths and asterionella. It has been our experience in the past, as it has undoubtedly been the experience of all other Sanitary

Engineers, that the treatment of water in open storage with copper sulphate for the reduction of microscopic organisms is almost immediately followed by an enormous increase in the bacterial content of the water. Investigation has shown this increase to be composed almost entirely of harmless saprophytic bacteria but for esthetic reasons, if for no other, it is desirable to avoid the phenomena. With this idea in view the speaker assisted by Mr. A. J. Feeney, the Superintendent of Filtration, decided to experiment with liquid chlorine, and determine whether its action on microscopic growths would not eliminate the objectionable features resulting from the use of copper sulphate.

An ordinary tank of gas containing about 150 pounds was placed in a large boat, and an 18 foot section of two inch rubber hose connected to the valve of the tank. On the end of the hose there was placed an ordinary copper watering spout sprinkler end. The water was treated with sufficient chlorine to give $\frac{1}{2}$ p.p.m. by rowing the boat carefully around the reservoir and discharging the gas into the water. The microscopic count before treatment was about 2500 per c.c., of which about 1500 were asterionella. Twenty-four hours after treatment the count was 900 per c.c.; the asterionella being practically eliminated. It was decided to treat the water a few days later with an equal amount of chlorine and as this experiment is being conducted at the present time the results are not available for presentation at this meeting.

The speaker believes that the use of liquid chlorine for the purpose outlined is a new one, and that it may prove to be decidedly more advantageous than the old method of copper sulphate—the process being one of oxidation rather than germicidal. The principal difficulty encountered is in obtaining the proper absorption of the gas by the water, but this may undoubtedly be overcome by a careful study of local operating conditions.

It is stated that Prof. Whipple, of Harvard University, is preparing to make experiments along the lines mentioned. His results will undoubtedly be of great interest to the Sanitary Engineering profession.

President Gwinn: The statement was made by some one that this process was a dangerous one, that there was danger of the attendants being overcome through the gas being allowed to escape. What can you tell us about that, Mr. Kienle?

Mr. John A. Kienle: Chlorine gas is not explosive. It is under a variable pressure in the cylinders which range from 54 pounds at 32 degrees Fahrenheit up to 125 pounds at 85 degrees Fahrenheit which may be considered a normal range for most parts of the country. The cylinders in which the chlorine is contained are imported from Germany. They are subjected to the rigid German Goverment tests of 1000 pounds per square inch and each cylinder must pass this official inspection before shipment, each having a card indicating that such test has been made and that the cylinder is approved.

Relative to the escape of chlorine, the speaker would hardly think that anybody could question the fact that chlorine gas in its pure state is poisonous; but when it is put into the water, it is used in such minute quantities that its effect upon the human system is negligible. Chlorine has been manufactured and liquefied for a period of about seven years and the statement is made that there has been no difficulty encountered, nor have there been any fatal accidents. The cylinder cannot blow out with an explosion discharging fragments for the reason that they are manufactured of wrought steel which splits or rips open rather than bursts as would be the case if the cylinders were made of cast iron or steel. If the cylinder burst in a closed gallery or room, the men in the neighborhood would no doubt be in danger unless they could readily escape to the open atmosphere. Experience, that those who have handled it have had, results in at least ordinary precaution to prevent any unnecessary chances being taken. If the operator should deliberately turn on the cylinder valve and if his position be such that he could not get away, there undoubtedly would be great danger of suffocation. The speaker has had two rather disagreeable experiences through inhaling chlorine gas, yet both were the result of deliberate carelessness. He was foolish enough in an endeavor to test the action of the absorption tower of the crude apparatus, shown in the photographs, to do so by using the sense of smell and as it happened that the chlorine gas was escaping to the atmosphere at the time, the effect was a rather excessive fit of coughing, which continued over a rather extended period, eventually causing nausea. The effect of chlorine gas is not that it makes you sick immediately, but that it causes excessive coughing until sickness results. It does not take any one very long to realize that chlorine gas is present in the atmosphere, the odor being a most penetrating one. However, with proper appliances for controlling it there

should be no escape to the atmosphere. The cylinder valves are so constructed that you can only get a limited quantity of chlorine through them. This is an important fact to remember when considering the possible dangers from the accidental escape of chlorine. If the valve is opened wide the rate of discharge becomes so rapid that the liquid gas freezes in the cylinder and eventually closes the opening in the valve. This, of course, is due to the rapid expansion of the gas and happened in one or two instances in the Philadelphia tests. Dr. Jackson has spoken regarding this particular point. We have found that at times some of the cylinders indicate the freezing action by the appearance of a frost coating around the bottom. This results in the reduction of internal pressures. However, this is taken care of in the apparatus by the regulating valves.

Mr. D. D. Jackson: In the Brooklyn apparatus the gas is sprayed into a depth of water of about six feet. No solution tank is used. The gas goes directly from the machine, through a tube and into the water.

Mr. John A. Kienle: There may be some questions in the minds of those present as to what causes this increased efficiency of liquid chlorine over hypochlorite of lime. The speaker has discussed this question with a number of members of the association, some of whom are not present and others mentioned by Dr. Jackson today. The chemical action has also been discussed with Dr. Jackson. You will recall from the remarks made in the paper and also from Dr. Jackson's remarks that it is stated that one pound of liquid chlorine will do the work of seven and one-half to ten pounds of hypochlorite powder. The speaker understood Dr. Jackson to say something like eight or nine pounds of hypochlorite powder. Hypochlorite powder is sold by manufacturers as thirty-five per cent strength. Actual tests made on quite a long run at Philadelphia water works show that the strength of bleaching powder varies from 33 to 38 or 40 per cent and that upon this basis the theoretical average amount of available chlorine in the hypo solution should have been something like 29.4 per cent. The actual titration tests figured out, however, that it amounted to only 25 per cent. Now, this would mean that one pound of liquid chlorine would equal the so called available chlorine from four pounds of hypochlorite powder. We are now speaking of one

pound of liquid chlorine to eight pounds of powder. This test shows that there must be a difference between the reaction of liquid chlorine and the actions taking place with the use of hypochlorite. Dr. Jackson offers a logical solution in his statement that the reaction is reversible.

The speaker's recollection is that when hypo treatment was first discussed before this association, in 1908, the destruction of bacteria was not attributed to the action of chlorine but was accounted for by the formation of hypochlorous acid due to the action of the carbonic acid in the water. The atom of oxygen supplied from the hypochlorous acid in the presence of oxidizable matter and the destruction resulted from the oxidation and not from chlorination. With the liquid chlorine, however, it would seem that primarily upon the introduction of pure chlorine into water there is a direct chlorine destructive action followed by the usual formation of hypochlorous acid, the oxygen causing oxidation in the same manner as in the hypo treatment. This permits the formation of hypochlorous acid which reacts with the carbonate present in the water to again form hypochlorous acid giving over another atom of oxygen. This the writer understands Dr. Jackson terms reversible reaction. The essential point, however, regardless of the chemistry involved, is that actual experience has demonstrated this increased efficiency of liquid chlorine.

WATER MOVEMENT COMPARED WITH AIR MOVEMENT AND ITS RELATION TO LAKE CONTAMINATION

By J. Walter Ackerman

The state of New York has a provision in its public health law similar, perhaps, to that of some of the other states, which gives to public water works the right to have sanitary rules enacted by the State Department of Health for the protection of the potable supply. These rules are written for each specified water supply, according to the requirements of their local conditions, and finally, to make them operative and valid, they must be published for a specified time in the local press circulated in and about the watershed.

The present sanitary rules for the municipal water supply of the city of Auburn, New York went into effect in May, 1906. The water department of that city immediately afterward began inspections, and also began to serve notices in all cases where violations of these rules were found. Either on preliminary notice of the department or a following later notice from the State Department of Health, a very large number of these violations were abated, none of any importance remaining except those within the limits of the villages of Moravia, Locke and Groton, which villages are distant four, seven and one-half and thirteen miles, respectively, from Owasco Lake.

In October and November, 1907, twenty cases of typhoid fever developed on the watershed. The major portion of these numbers were in Moravia or this immediate vicinity. In the following spring a small epidemic of typhoid fever occurred in Auburn, fortyfive cases having been reported to the Health Department of the city of Auburn, but there were twelve deaths. Allowing the usual percentage of fatality, this would indicate that there were probably upwards of a hundred cases, the rate for the year 1908 being 46.8 per hundred thousand.

This epidemic was investigated by Professor Olin H. Landreth of Union College, and later his data were studied by Professor George C. Whipple, now of Harvard University. Both of these eminent

gentlemen agreed that while no particular case or cases that caused the epidemic could be determined, the circumstantial evidence was so strong as to make it practically certain that the Auburn epidemic was caused from infection of the water supply. Professor Whipple further adds: "That it was possible, under the circumstances, for pollution to pass from Moravia to the intake of the Auburn supply, I see no reason to doubt."

Upon receipt of Professor Landreth's report the Water Commissioners, in order to fortify future action, asked Mr. Whipple to make a complete and thorough examination of the water works system, and to file a report, with recommendations on the same. Upon the receipt of this report the commissioners proceeded to carry out the recommendations, and among many things, proposed to build a slow sand filtration plant. But this latter project could only be accomplished by a referendum vote of the people. An antagonistic press, and the forgotten typhoid fever epidemic of the year before, defeated the proposed work.

After the defeat of the filtration plant idea the writer, who became chief engineer and superintendent in 1908, just after the typhoid fever epidemic hereinbefore mentioned, was directed to build a hypochlorite disinfecting plant for emergency conditions, to be used whenever the water gave evidence of being polluted. This plant has been operated with the usual success of such plants, down to the present time.

The only other plan now left for further improving the quality of the water supply was to attempt further elimination of the sanitary violations still existing on the watershed, and particularly those cases which had not complied with our own previous notices, and which also had failed to obey those of the State Department of Health. Our experience in a few minor test cases was that it was practically impossible to secure verdicts before local magistrates, due to the feeling existing that the people on the watershed were being deprived of their rights by a foreign corporation.

In order to test the legality of our position, and to outline a future policy as to violations, it was determined to carry to the supreme court a test case. But through previous experience, and by the advice of attorneys, it was finally decided to try the remedy by indictment. The largest violator, and the most impersonal one, was the Union Free School of Moravia, a graded school having between three and four hundred pupils. The sewer from this school discharged directly into Mill Creek, one of the tributaries of the

main inlet about four miles from the head of Owasco Lake, which is the supply for the city of Auburn. The Water Board, through the District Attorney's office, secured an indictment before the grand jury of the members of the Board of Education of the Union Free School, District No. 1, town of Moravia. After a number of delays the case was finally brought in the supreme court, before Mr. Justice William W. Clark, on April 26, 1913.

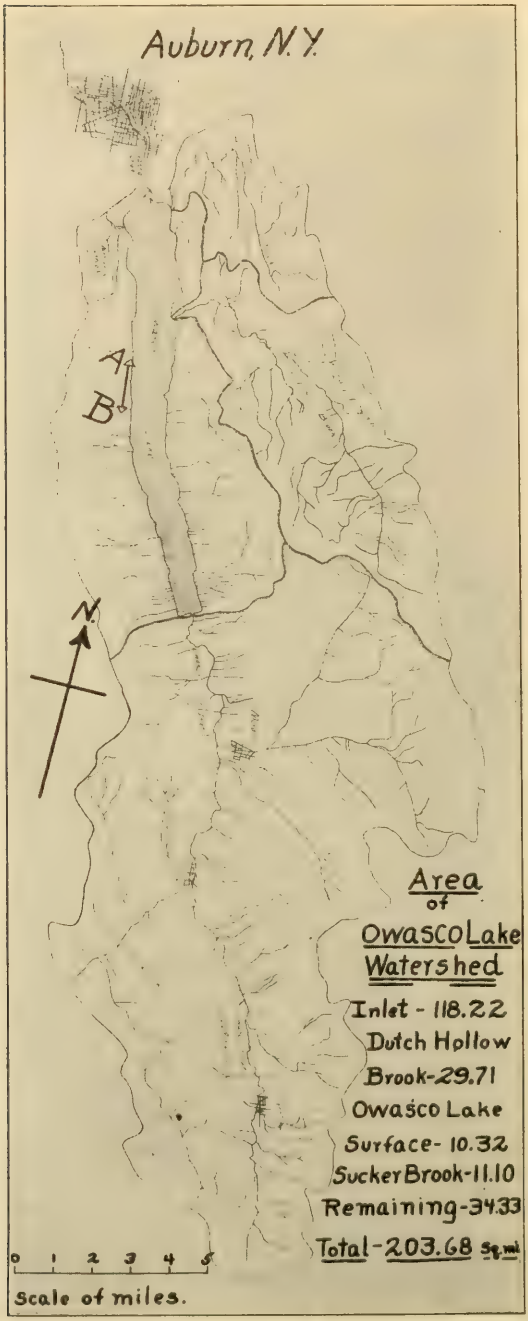
Owasco Lake is one of the socalled finger lakes of central New York, and like the others in the series, is a long, narrow body of water, its long dimension of about 10 miles being approximately north and south; it has a surface area of 10.32 square miles, a land watershed of 193.36 square miles. The main inlet, which enters at the south end of the lake, drains over 60 per cent of the watershed area. Practically all of the sewage pollution on the entire watershed comes into the lake through this main inlet from the villages of Moravia, Groton and Locke, the first two having less than two thousand inhabitants, and the latter only a few hundred.

The city of Auburn, New York, gets its supply from this lake, through an intake pipe from the opposite (or north) end of the lake, at a point about onehalf a mile from the north shore, at a depth of 40 feet.

This location gives to the city by natural agencies the protection of this immense reservoir, to keep the infection that may come in at one end of the lake from reaching the water supply drawn from the other end. And while this has generally been regarded as giving an adequate protection, or at least a feeling of security, due to the intervening miles, yet our typhoid fever investigation, and Professor Whipple's studies in relation thereto, together with his bacterial charts, practically proved the fallacy of our belief.

As before noted, the case was brought by indictment. The reason for this was that the State Department of Public Health, while it decided questions of sanitary violations, had not the direct power to enforce abatements on its own decision, as this authority (section 71 of Chapter 661 of the Laws of 1893, New York) is vested in the local boards of health, who are generally unwilling to act, either through local prejudice or a failure to realize the danger of the pollution. And before the mandate of the law could be made effective, the state must prove that a nuisance existed. So that brought us back to the original starting point.

Also, if put into the hands of the State Department of Health they might require that the abolishment of the violation should be



OWASCO LAKE AND WATERSHED AND BASE LINE A.B. FROM WHICH OBSERVATIONS WERE TAKEN

effected at our expense, and this appeared to be questionable propriety, to pay for what we considered other people's wrongs. A recourse to civil action, even if successful, might be carried on appeal and consume several years before a final determination could be reached, while an indictment, if a verdict was secured, was not subject to such extended legal delays. Consequently, the case was brought under sections 1530 and 1532 of the Penal Code of the State of New York, which sections follow:

Section 1530. Public Nuisance Defined.

A "public nuisance" is a crime against the order and economy of the state, and consists in unlawfully doing an act, or omitting to perform a duty, which act or omission:

1. Annoys, injures or endangers the comfort, repose, health or safety of any considerable number of persons; or,

2. Offends public decency; or,

3. Unlawfully interferes with, obstructs, or tends to obstruct, or renders dangerous for passage, a lake, or a navigable river, bay, stream, canal or basin, or a stream, creek or other body of water which has been dredged or cleared at public expense, or a public park, square, street or highway; or,

4. In any way renders a considerable number of persons insecure in life, or the use of property.

Section 1532. Maintaining Nuisance.

A person who commits or maintains a public nuisance, the punishment for which is not specially prescribed, or who wilfully omits or refuses to perform any legal duty relating to the removal of such a public nuisance, is guilty of a misdemeanor.

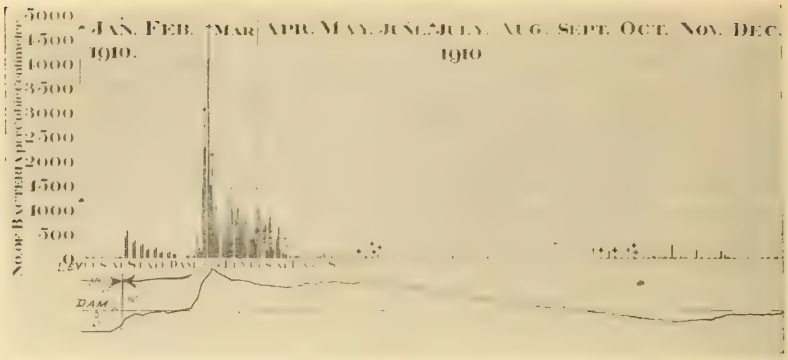
A perusal of this will convince anyone that it is very broad, and will cover almost any sort of a violation. And it would seem that it is in general, a good legal weapon to use in such cases as this.

The main points of the contention of the water board were, that the members of the Board of Education of this school were guilty of a misdemeanor in operating and maintaining the sewer from the high school to the bank or shore of Mill Creek for the purpose of conveying excrement from the students of the school to the bank of said creek and to the inlet waters of Owasco Lake.

1. The accumulation of excrement upon the bank of the creek offends public decency, annoys and endangers the health of the citizens of Moravia by foul odors, and the possibility of disease being transmitted by flies.

2. The possibility of this probable infection reaching the water supply of the city of Auburn, a distance of some fourteen miles.

Realizing that our case would fail unless we could prove this last proposition, some special experiments were undertaken by the

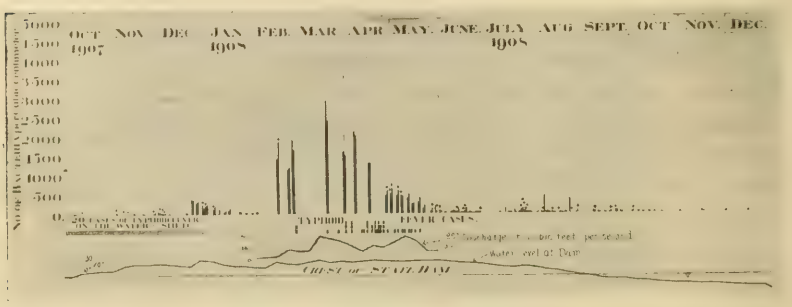


Bacterial Chart and Water Levels. The + Marks Indicate Presence of B. Coli.

writer, upon the suggestions of Professor Whipple. These were to establish, if possible, the fact that the wind blowing across the waters of the lake would create surface currents of sufficient velocity to bring polluted water from one end of the lake to the other well within the vigorous lifetime of dangerous pathogenic bacteria.

The case was ably presented by the local district attorney, assisted by eminent counsel, and Professor Whipple acting, not only as one of the consultants, but as special advisory engineer to the attorneys for the water board.

For a long period of time frequent bacteriological examinations of the city water have been made, and Professor Whipple assembled on a chart accompanying his original report the results of such examinations for over a yearly cycle, together with some associated data of the same period. Later similar results have received the same treatment, down to the trial of our case. These charts were



Bacterial Chart with Water Levels at Discharge and Typhoid Fever

made 10 or 12 feet in length, and exhibited in court by means of elevated easels, so that they were before the jury at all times.

The bacteriological examinations from which these charts were made were proved by Dr. Willis W. Waite and Dr. F. M. Meader, the two bacteriologists who have made the examinations of the city water for the period shown. Dr. Meader also exhibited to the jury under the microscope, living typhoid fever organisms, and it was accomplished in a period of seven minutes. He also exhibited a chart showing the method of growth of some bacteria under favorable conditions, showing the enormous number that could develop in twentyfour hours as being something over two hundred and eighty millions of millions.

Professor Henry N. Ogden of Cornell University, professor of sanitary engineering, was called to testify in relation to the violation in question, as he was at that time the special representative of the State Department of Health who made the examinations and decided the violations for the state department. He also gave the histories of a number of waterborne typhoid fever epidemics with which he was familiar throughout the country.

Professor C. E. A. Winslow, professor of bacteriology in the College of the City of New York, one of the leading bacteriologists of this country, was called to testify in relation to the following:

1. The dangers of fecal matter, under the following subheads:

(a) General principles of the transmission of communicable diseases; (b) the prevalence of typhoid fever among High School pupils, and typhoid fever carriers; (c) number of typhoid fever bacilli in fecal matter, in urine; (d) other diseases transmitted through fecal matter, dysentery, tuberculosis, children's diseases.

2. Fly transmission of diseases. Local dangers at Moravia.

3. Life of typhoid fever bacillus in water. Examples of waterborne typhoid fever at other places.

He exhibited models showing the similarity of the B. coli type of bacteria and those causing typhoid fever. He also showed to the jury the results of a prior fortyeight hour bacteriological examination of water polluted with excrement, and also showed the technic of performing this examination. This was to impress upon the jury the meaning of the black crosses on the bacteriological charts, placed there to indicate B. coli.

The last witness, Professor William P. Mason of the Renesselaer Polytechnic Institute, with his experience in water pollution cases from Maine to California, and from the north tier to the Gulf of

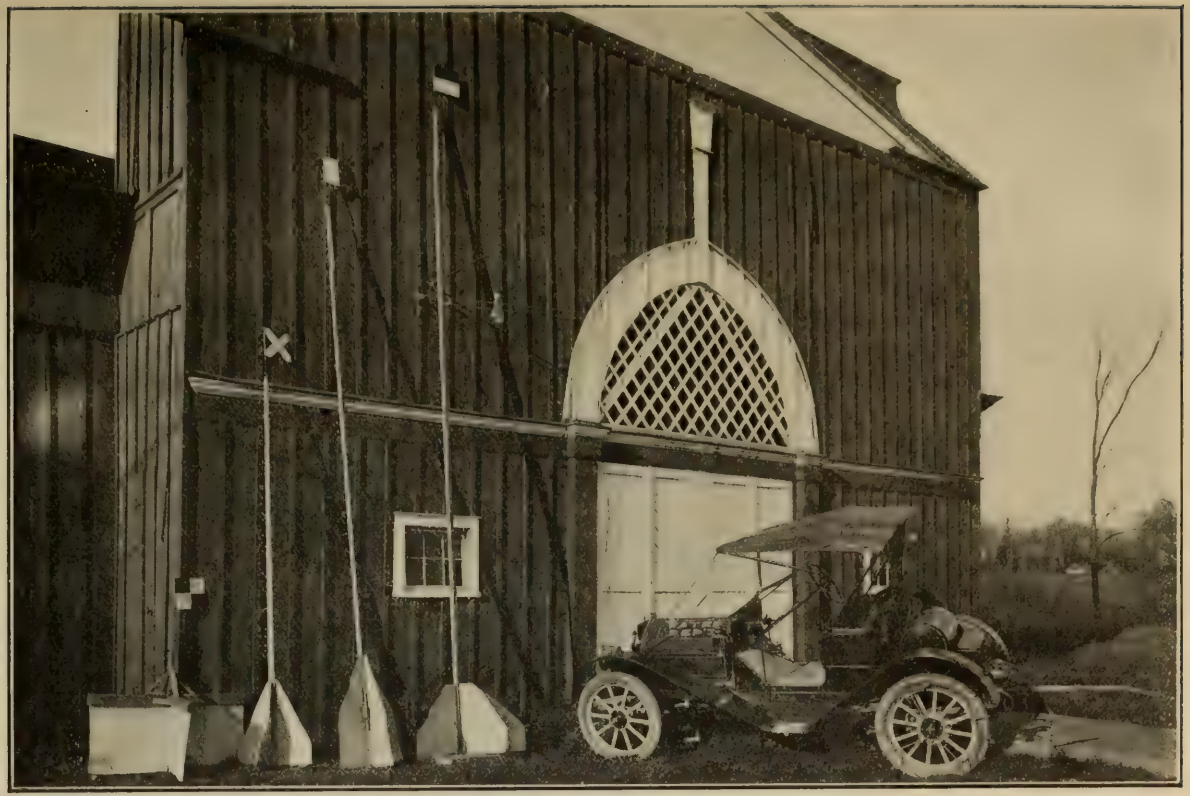
Mexico, closed the same in a very convincing manner by substantiating and backing up some of the previous testimony, and finally stating that owing to the proof submitted, he believed that it was entirely possible for typhoid fever to get from the sewer discharging from the high school at Moravia into the Auburn water supply, and further, gave it as his opinion that the typhoid fever epidemic of Auburn, in the spring of 1908, was caused by the outbreak of typhoid fever in and about the village of Moravia, of the winter before.

Prior to the evidence of the witnesses above mentioned, the writer testified in relation to the surface currents in the lake caused by wind action. And in order to understand the conclusions presented, the following description of the experiment is offered:

The method of operation was to place some specially designed submerged floats of varying depths in the waters of Owasco Lake and note their movement, both as to direction and velocity, thus giving a knowledge of the currents in the lake. And in order to compare this with the wind movement, one of the standard recording anemometers such as are used by the Weather Bureau of the United States was installed and placed in operation at the exposed end of the state pier out in Owasco Lake.

This instrument, as some of you well know, automatically records the velocity of the wind and the direction for eight points of the compass. There were five floats constructed: Nos. 1 and 2 were in equilibrium at a depth of 5 feet, No. 3, 10 feet, No. 4, 15 feet, and No. 5, 20 feet. The only projection above the water was a slender pole about 6 inches high and less than one inch in cross sectional area. From the top of this was supported a very light tin telltale flag 10 inches square, free to revolve about a vertical axis; and on each, in red and white, was a special symbol to designate each float. At the submerged bottom end of each two large vertical sheets of light galvanized metal were placed and held at right angles to each other, so that whatever phase was presented to the currents of the water it would be substantially of the same area. Over 99 per cent of the surface was submerged, and over 95 per cent of the surface was at the depths as indicated.

In order to determine the movements of the floats, a base line was established between two prominent hills beside the lake. Observers with watches timed alike were stationed at those two points, and angle readings were taken on each float at every 15 minute interval, and they were so planned that an observation was made



TYPES OF SUBMERGED FLOATS SHOWING DIFFERENT DEPTHS OF IMMERSION AND ON EACH A SPECIAL TELL TALE FLAG

every 3 minutes. This gave sufficient data so that the coördinate position of each float was computed to the nearest tenth of a foot for every observation, this of course giving its direction and velocity for any period covered by the experiment. All of these results have been plotted to make a study of the same. And in order to make a comparison of this movement of the waters of the lake with that of the wind, the anemometer charts have been tabulated hour by hour, and these results also plotted.

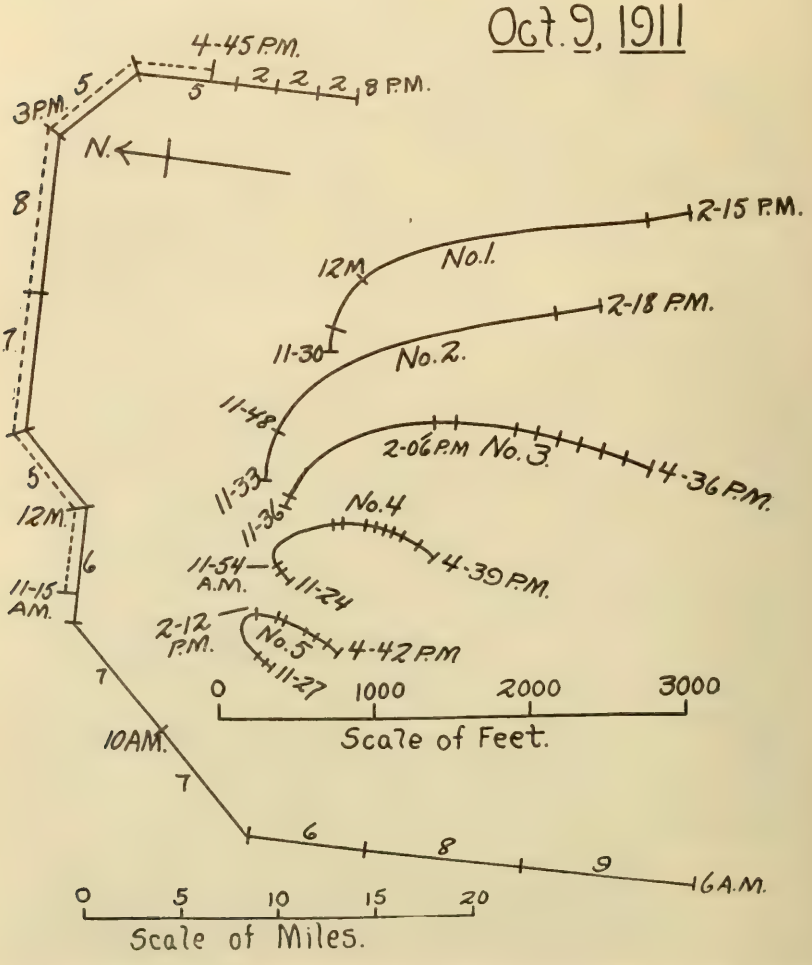


Chart Showing Wind Movement and the Resultant Movement of the Water as Shown by the Path of Floats

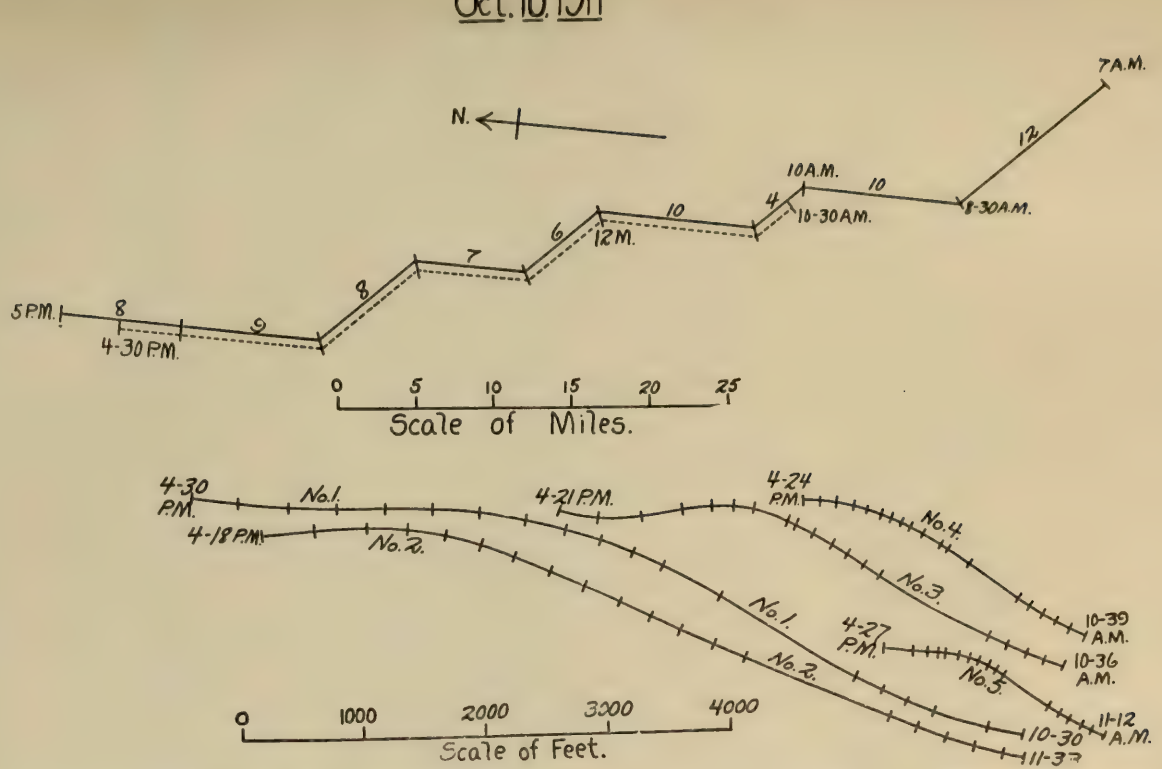


CHART SHOWING WIND MOVEMENT AND THE RESULTANT MOVEMENT OF THE WATER AS SHOWN BY THE PATH OF THE FLOATS

Some of this data, assembled on the charts dated October 9, October 10, October 12, October 26, and November 4 show to a scale the paths taken by the floats, and also the path and the movement of the wind for the same period, and for some hours previous.

The dotted line alongside of the wind chart shows the period during which the floats were being observed. The short cross lines at right angles to the paths of the floats show the computed points of the position of the floats, and some of the critical ones are labeled with the time of observation. Similar cross lines at right angles to the path of the wind denote the hour of the day. These are also marked at some of the principal or critical points. The figures on the wind chart between these points denote in miles the movement of the wind during the hour period.

On October 9 is exhibited a complete change of the wind from the south at 6 A. M. to north at 4 P. M. The floats were put in the water between 11 A. M. and 12 M., and while Nos. 1, 2 and 3 almost immediately followed the direction of the wind blowing at that time, Nos. 4 and 5, the 15 and 20 foot floats, continued for a time in the direction the wind had been blowing a number of hours previous, the 20 foot float not changing its direction for some time afterward.

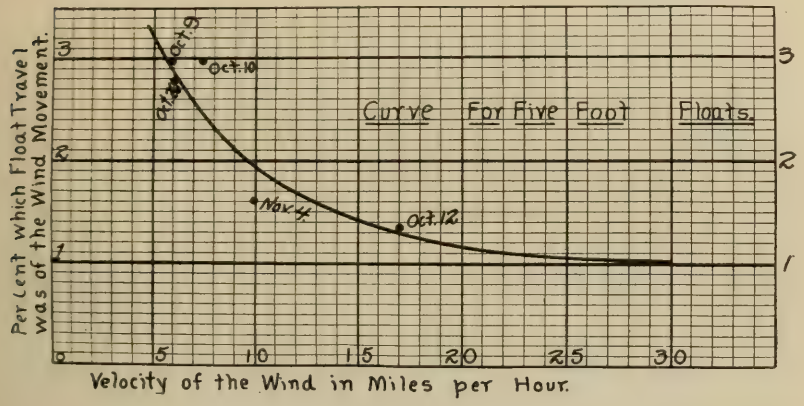
Similarly, studies may be made of the records of the floats for the different days, as exhibited. But for purposes of determining the rate of the movement of water, as compared with that of the wind, actual tabulations of this have been made, and the tables presented under the heading of "Tabulations of Water and Wind Movement" are some of the results of comparing the movement of the water with the movement of the wind, both as to actual direction and translation. But, as it is to be noted that the lake is approximately only onetenth as wide as the length of the same, it was observed that when the wind blew at an angle to the long axis of the lake the resultant movement of the water was generally more nearly parallel to the axis of the lake than to the direction of the wind. And as this axis is practically north and south, a second series of tabulations compares the north and south components of the wind movement and the resultant north and south components of the water movement.

RELATION BETWEEN WIND MOVEMENT AND TRAVEL OF THE SURFACE WATER

From the first tables above mentioned a plotting was made as shown on chart labeled "Curve for Five Foot Floats," using wind

velocities in miles per hour as abscissae, and the percentage which the water travel was of the wind movement, as shown by an average of the 5 foot floats, as ordinates. From this curve the following results were deduced:

Velocity of wind, miles per hour..	5	10	15	20	25	30
Percentage which water travel was of wind movement.....	3.25	1.95	1.40	1.15	1.05	1.00
Wind movement in miles required to cause the water to travel 10 miles	307	512	714	869	952	1000
Number of hours of wind at the given velocity required to cause the water to travel 10 miles.....	61.4	51.2	47.6	43.5	38.1	33.3



CURVE DEDUCED AS EXPLAINED IN ABOVE PARAGRAPH

Another plotting and curve were made from the same tables, using the values obtained by taking the average of the 5 and 10 foot floats. From this curve the following results were deduced:

Velocity of wind, miles per hour..	5	10	15	20	25	30
Percentage which water travel was of wind movement.....	3.2	1.8	1.3	1.05	.95	.90

Wind movement in miles required to cause the water to travel 10 miles	313	555	769	952	1053	1111
Number of hours of wind at the given velocity required to cause the water to travel 10 miles	62.6	55.5	51.2	47.6	42.1	37.0

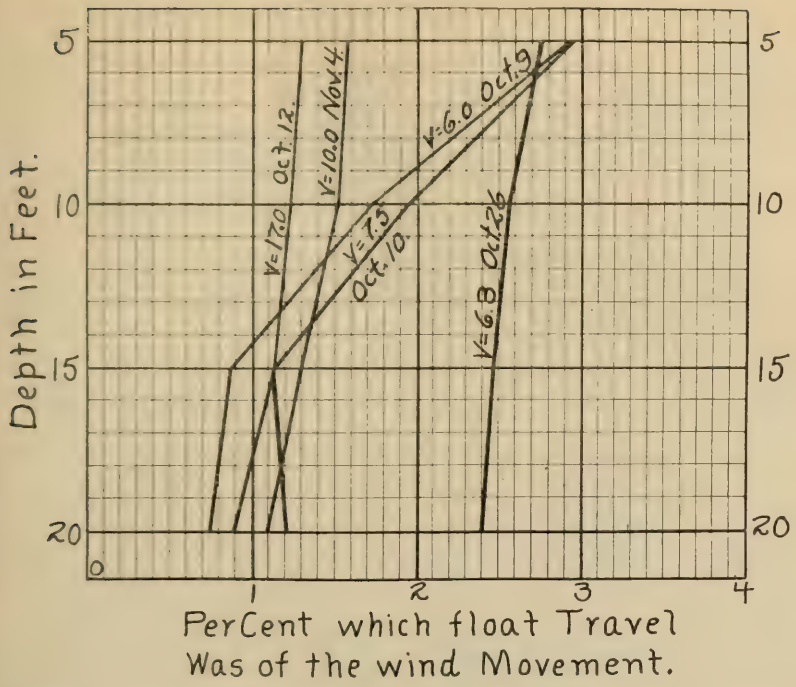
Lastly, from the same tables the average of all the floats was used in plotting a curve, and the following results were deduced:

Velocity of wind, miles per hour	5	10	15	20	25	30
Percentage which water travel was of wind movement	2.8	1.5	1.25	1.15	1.05	1.00
Wind movement in miles required to cause the water to travel 10 miles	357	666	800	869	852	1000
Number of hours of wind at the given velocity required to cause the water to travel 10 miles	71.4	66.6	53.3	43.5	38.0	33.3

Similar data were tabulated, using the north and south components of the wind movement and watermovement, and the results obtained from plotting this second series, of north and south components of movement, differ but slightly from those given above. At a wind velocity of 5 miles per hour the percentage of water travel is practically the same, while for the higher velocities it shows an increased value.

Another plotting has been made with the percentages which the water movement is of wind movement, as abscissae, and depths as ordinates. This shows that with the wind blowing at seven miles or less an hour there is a marked difference between the percentage of movement of the surface water and the deeper layers, while at the higher velocities no such marked differences exist.

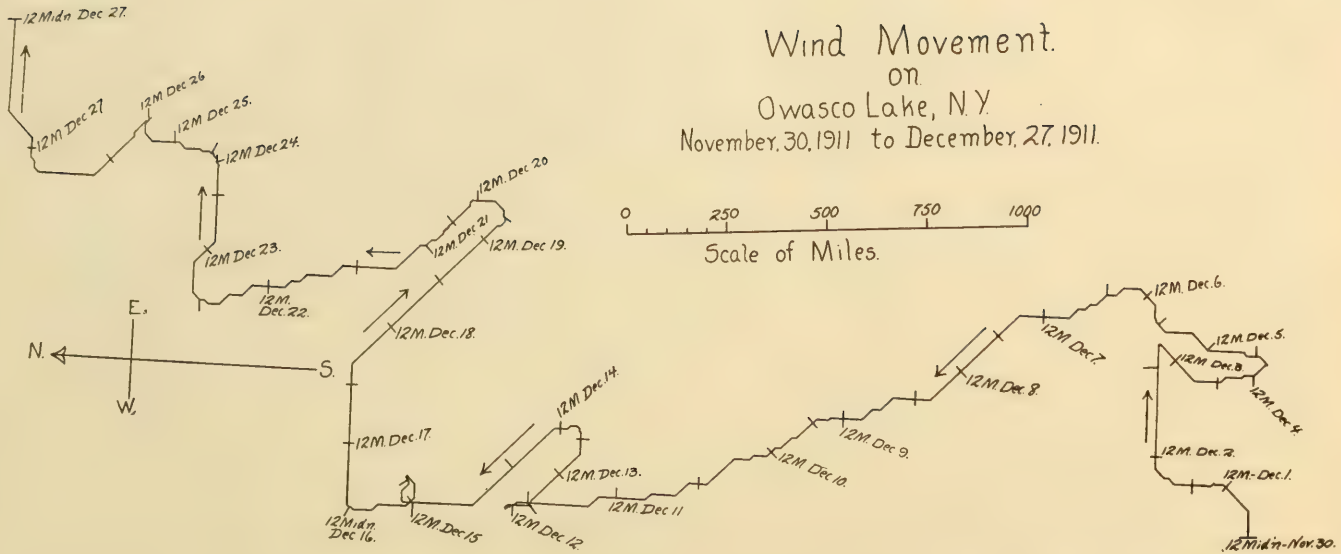
A summary of some of the results of these experiments brings out the following:



The anemometer records proved conclusively that the south and southerly winds, the ones bringing pollution toward our supply, were the ones that blew for continuous periods the longest and the strongest, and also that the summation of the movement of the wind was generally always to the north by a very large amount.

The water movement induced in the lake by winds diagonal at the long axis of the same had a tendency to take a direction parallel to the axis; thus giving not only the south wind, but the wind from either south quarter, an opportunity of keeping the water in the surface of the lake moving towards our supply.

At the lower wind velocities, the floats prove that the percentage of water movement to wind movement is not only greater than it is at higher velocities, but that the surface movement of water is greater than that of a lower strata. So that if pollution was being carried in the upper strata of water, as this is the place it must be received from the inflowing streams, the higher velocity of the upper layer of water will have a tendency to hold the pollution in suspension, and hence, carry it with it.



WIND CHART. SHOWING THAT THE MOVEMENT IS IN GENERAL FROM THE SOUTH TO THE NORTH

From the above review of the facts as noted, while not applicable to all large reservoirs, the conclusion reached in this particular case, by very conservative interpretations of the experimental results, is that at many times polluted water could be brought from one end of the lake to the other, a distance of ten miles, in a period of from two to three days.

Tabulation of Water and Wind Movement

October 9, 1911

FLOAT NO.	TIME	TRAVEL OF FLOATS		WIND MOVEMENT		PER CENT WHICH FLOAT TRAVEL WAS OF WIND MOVEMENT
		Feet	Feet per hr.	Miles per hr.	Feet per hr.	
1	12:00–2:15	2,150	956	6.0	31,680	3.02
2	11:48–2:18	2,290	916	6.0	31,680	2.89
3	2:06–4:36	1,400	560	6.1	32,208	1.74
4	2:09–4:39	700	280	6.1	32,208	.87
5	2:12–4:42	600	240	6.1	32,208	.75

October 10, 1911

FLOAT NO.	TIME	TRAVEL OF FLOATS		WIND MOVEMENT		PER CENT WHICH FLOAT TRAVEL WAS OF WIND MOVEMENT
		Feet	Feet per hr.	Miles per hr.	Feet per hr.	
1	10:30–4:30	7,180	1,197	7.5	39,600	3.02
2	10:33–4:18	6,660	1,148	7.5	39,600	2.90
3	10:36–4:21	4,500	772	7.5	39,600	1.95
4	10:39–4:24	2,600	452	7.5	39,600	1.14
5	10:42–4:27	2,030	353	7.5	39,600	.89

October 12, 1911

FLOAT NO.	TIME	TRAVEL OF FLOATS		WIND MOVEMENT		PER CENT WHICH FLOAT TRAVEL WAS OF WIND MOVEMENT
		Feet	Feet per hr.	Miles per hr.	Feet per hr.	
1	1:15–4:30	3,750	1,154	17.0	89,760	1.29
2	1:18–4:18	3,550	1,183	17.0	89,760	1.32
3	1:21–3:51	2,750	1,100	17.0	89,760	1.23
4	1:09–3:54	2,810	1,022	17.0	89,760	1.14
5	1:12–3:57	3,020	1,098	17.0	89,760	1.22

January - 1908.

Date	S.E.		South		S.W.		Total		
	hr.	mi.	hr.	mi.	hr.	mi.	hr.	mi.	
19	2	21	1	12			3	33	
20	12	218	11	131	1	6	24	355	
21	10	165	14	144			24	309	
22	1	16	2	31	1	8	18	55	
Total							69	752	
Rate	10.9 miles per Hour.								
24	2	13					2	13	
25	4	35	6	42	13	220	23	297	1hr.-E.-11mi.
26	10	245	12	182	2	17	24	451	
27			2	18	3	44	5	62	
Total							54	823	
Rate	15.3 miles per Hour.								

1909

Date	S.E.		South.		S.W.		Total		
	hr.	mi.	hr.	mi.	hr.	mi.	hr.	mi.	
Jan. 21	14	206	10	136			24	342	
22	18	168	6	58			24	226	
23	19	229	5	54			24	283	
24	9	83	11	111			20	194	
Total							92	1045	
Rate.	11.3 miles per Hour.								
April. 11	13	178	2	11			15	189	
12	17	450	7	204			24	654	
13	16	587	6	237			22	824	
Total							61	1667	
Rate	27.3 miles per Hour.								
June 9	24	269					24	269	
10	18	173					18	173	
Total.							42	442	
Rate.	10.5 miles per Hour.								
August 12	11	112	5	62	3	54	19	228	
13	21	221	2	15			23	236	E.-1hr.-6mi.
14	23	432	1	16			24	448	
15	22	495	2	55			24	550	
16	17	321	7	72			24	393	
Total							114	1855	
Rate	16.2 miles per Hour.								

SPECIFIC RECORDS OF CONTINUOUS WINDS FROM THE SOUTH TO THE NORTH

October 26, 1911

FLOAT NO.	TIME	TRAVEL OF FLOATS		WIND MOVEMENT		PER CENT WHICH FLOAT TRAVEL WAS OF WIND MOVEMENT
		Feet	Feet per hr.	Miles per hr.	Feet per hr.	
1	1:00–3:15	1,960	871	6.3	33,264	2.62
2	1:03–3:18	2,170	934	6.3	33,264	2.90
3	1:06–3:06	1,710	855	6.3	33,264	2.57
4	1:09–3:09	1,640	820	6.3	33,264	2.47
5	1:12–3:12	1,590	795	6.3	33,264	2.39

November 4, 1911

FLOAT NO.	TIME	TRAVEL OF FLOATS		WIND MOVEMENT		PER CENT WHICH FLOAT TRAVEL WAS OF WIND MOVEMENT
		Feet	Feet per hr.	Miles per hr.	Feet per hr.	
1	1:00–4:00	2,450	817	10.0	52,800	1.55
2	1:03–3:48	2,350	855	10.0	52,800	1.62
3	12:51–3:51	2,420	806	10.0	52,800	1.53
4	12:54–3:54	2,060	686	10.0	52,800	1.30
5	12:57–3:57	1,710	570	10.0	52,800	1.08

The lake is 160 feet deep. That is about its greatest depth. At the time observations were being taken of these floats we took the temperature measurements at our station daily, both of the water going through the pump and the water on the surface. There was no particular change in surface temperature during the period of these experiments. However, occasionally at times there were changes of temperature of as much as ten or twelve degrees inside of five minutes due to the wind pulling the water up, becoming very warm.

DISCUSSION

Mr. W. F. Wilcox: This paper shows that considerable money and time have been spent very intelligently and the Association should feel itself under obligation to Mr. Ackerman for his valuable contribution. Information of this character, so thoroughly and intelligently prepared, and so well presented, is very valuable. This is especially true of a paper which goes so thoroughly into the care and management of a reservoir which is drawn upon for domestic water supply.

The speaker does not wish to have it understood that he is in

any way antagonistic to the conclusions drawn by Mr. Ackerman; but rather wishes to add to the information on the care of reservoirs. Having had the opportunity to study reservoirs for storage of water, for both domestic and manufacturing purposes, during the past ten years, his intention is not to criticise Mr. Ackerman and his conclusions; but to give an experience which led to different conclusions.

One reservoir was made by throwing up embankments and only moving such material as necessary for construction. The land was denuded of trees and bushes; but stumps were left, and in considerable part of the reservoir, the original earth was not disturbed; but it is believed that all really objectionable matter was removed. The water in this reservoir was followed from time to time by analysis, by some of the foremost sanitary chemists in the United States, and it was always found to be of a very high quality.

The speaker constructed another reservoir at the same point and was careful to remove all the top soil, and in several points of the reservoir where the bottom was not good, the material was either removed or covered over with two feet of good red clay.

The second reservoir, although it was carefully followed when filled, provided a water which was not altogether satisfactory for the first year; but after the first year there were no objectionable features found in the water. The water from a sanitary standpoint, even during the first year, was a safe water filtered, showing a very satisfactory effluent, both chemically and bacteriologically; from a mechanical standpoint, it was noted that the water from the new reservoir caused corrosion of the boilers used by the manufacturing plants. This experience seems to have been corroborated by the experience of Mr. Eugene Carroll of Butte, Montana. (See Proceedings of the New England Water Works Association.)

The speaker, for the past three years, has been in charge of a reservoir of which the general shape and conditions are similar to the Auburn reservoir. This reservoir was formed by building a dam, with a spillway on the side and the impounding of waters of Village Creek. The water in the reservoir has a total water surface of about three hundred and fifty acres, and a maximum depth of eighty feet, with an ultimate capacity of six and a half billion gallons.

Village Creek is a stream fed by seventy-three miles of watershed with an average rainfall of fifty-four inches per annum. This stream arises at a point on the outskirts of Birmingham, to the

northeast of the city. The flow of the creek ranges from a minimum of five second feet, and a maximum of 40,000 second feet, with an average of 40 second feet. It winds its way through the northern part of the city, passing several pipe foundries, blast furnaces, coal mines, steel mill and a few other industries. In addition to the possible pollution from these sources it gets a possible pollution from the surface drains, and when the reservoir was first completed it received about four million gallons a day of sewage.

Although this reservoir was constructed for a mechanical water supply, the question entered the minds of the company of "How to care for the reservoir?" It was feared that with the various branches emptying in the reservoir, it might at some future time become so filled with putrescible matter as to be objectionable, causing sickness to the adjacent population. It was, therefore, determined, to take all possible precautions during construction, and to keep daily observations of all physical conditions, and to make periodical examinations; which would keep the management well advised as to the sanitary conditions.

The periodical examination consisted of chemical analyses, both quantitative and sanitary, and bacteriological examinations. However, the first step to be taken was to remove as nearly as possible all sources of contamination. To this end a thorough sanitary examination was made of the entire watershed. A pipe line eight miles long was constructed, to remove waste from a by-product plant (Semet Solvay process) beyond the watershed. An up to date sewage disposal plant was erected, which turns the sewage into the reservoir, under present conditions, with a maximum of fifteen grains of animal and vegetable matter per gallon, and by methylene blue tests, shows the effluent to have stability of 99. Incinerating plants were also constructed along the watershed, where the refuse and garbage were burned.

At coal mines and washers, settling arrangements were constructed, and all tailings from the mines were settled out before the wasted waters were allowed to enter the reservoir. Care was taken to prevent, as far as possible, any other known contamination.

Coming back to the reservoir itself, it may be noted, that in the constructions all vegetable and animal matter was removed before the impounding of the water, by the removal of the ground surface.

The reservoir is formed by damming Village Creek, into which

empties three small branches. The intake of the pumping station is located on Camp Branch about one half mile from Village Creek, which it joins at a point about two miles above the spillway.

It has been very gratifying to note that we have been able to keep the water from a reservoir of this class in a reasonably safe condition.

As it has been said, this reservoir is daily observed, records are kept of the temperatures, rainfall, humidity, evaporation and temperature of the water at three different points in the reservoir, which are selected to make an average.

These water temperatures are taken, starting at the surface and sampling every five feet down. It has not been noted that the wind has much control of the conditions as had been the experience at Auburn. It is granted that such pollution, if of light specific gravity, will be carried some distance by the wind, and at times this pollution may settle, contaminating the lower strata. It is believed that where the water is quiescent the wind will not have as marked effect upon the under currents as the temperatures will have.

It is hardly practicable in the discussion of another paper to go into details such as will establish all the points mentioned; but it is believed that the points brought out in this discussion may be sufficient to establish the fact that with peculiar local conditions, such as existed at Auburn, contamination may follow what would seem to be a rather small quantity of objectionable matter emptied under certain conditions into a reservoir.

But even under trying conditions, it has been clearly demonstrated that a lake or reservoir may be protected, so that it will be free from mosquitoes and that, although the water may not be classed as a strictly safe water, it will be known, that, should occasion arise, the water may be filtered and used for domestic purposes, without any apprehension of harmful results.

Mr. J. Walter Ackerman: A long narrow lake in a valley with prevailing winds in one direction has a tendency to be particularly liable to such wind movement, while it might not affect other reservoirs in the same way at all. We were simply proving our own case and not making any general statement.

Mr. George C. Whipple (presented by Mr. Longley): The writer has enjoyed reading Mr. Ackerman's very interesting paper which describes how the public water supply of the city of Auburn

became infected with typhoid fever germs, which, in all probability, traversed Lake Owasco for a distance of several miles before reaching the intake of the water works.

The situation there is probably not unique, but one which has not been given due consideration heretofore. It brings up the necessity of considering very carefully the nature of the currents that occur in large bodies of water. There are only a few instances on record where careful studies have been made by means of floats or by other means to determine what effect wind has upon the surface currents, and still fewer instances are on record where the bottom currents have been studied. The data obtained by Mr. Ackerman are, therefore, most welcome. But in using them it must be remembered that they apply only to this particular lake, or to lakes similar to it. Experiments made in Lake Erie, where the sweep of the wind was much greater, gave somewhat different results.

Last summer the writer, assisted by Mr. Melville C. Whipple and Dr. John W. M. Bunker of Harvard University, made a study of the currents in Lake Ontario in the vicinity of Rochester by means of the thermophone. The results of this investigation will soon be published in a report made by the writer to the City Engineer, Mr. Edwin A. Fisher.

Briefly, they showed the importance of the deep return currents, or the undertow currents, produced by a wind blowing towards the shore. At Rochester these outward bottom currents extend for many miles into the lake. They have a very important bearing upon the dispersion of sewage discharged into the lake.

The study of limnology has not received the attention in this country that it has abroad. Some interest was aroused about fifteen years ago and an American Limnological Commission, of which the writer was a member, was formed. This commission never accomplished any practical results and soon went out of existence. Since then the subject has been kept alive by a few scientists scattered over the country, notably by Dr. E. A. Birge of the University of Wisconsin. Interest in the subject, however, appears to be reviving. During the coming summer a course in limnology is to be given by the Sanitary Engineering department of the School of Engineering in Harvard University at the summer camp at Squam Lake. A hydrographic survey of a portion of the lake will be made and the temperature of the water at different depths will be studied. Observations of currents and seiches are to be made, besides microscopical examinations of the water and

determinations of the amount of dissolved oxygen and carbonic acid at different depths. Studies of the plankton will also be made by means of a plankton net. Following that, the students will visit some of the reservoirs of the Boston water supply and undertake similar investigations. Part of this work will be done in coöperation with the Chief Engineer of the Metropolitan Water Board, who has requested the writer to make a limnological study of some of the reservoirs of the Boston water supply during the coming summer. Similar studies are also being made at the present time at Fresh Pond, Cambridge, Mass. This course is attracting the attention of many who are not students in the School of Engineering, and a number of engineers are planning to avail themselves of the opportunity offered by Harvard University to take up this work as a special study.

It is hoped that the result of these studies will stimulate the general interest of water works officials in this important science, which so closely involves the effect of storage on the quality of water.

Dr. William P. Mason (by letter): Mr. Ackerman has certainly presented a most interesting paper, although in his method of presentation he hardly takes as much credit as is due him. He is the man that did the great bulk of the work, although Professor G. C. Whipple has had no small share in it as well.

As Mr. Ackerman has noted, Owasco Lake is long and narrow, having a surface approximately represented by a length of ten miles and a width of one, and to it is tributary a land watershed of about 193 square miles. The peculiar feature of the case which has especial interest to the writer is the possibility of polluting material of fecal character being transported from the village of Moravia down the inlet stream and then northward the entire ten miles of the lake's length to the intake of the city of Auburn.

We have all faithfully held to the dictum that sedimentation and time were the great purifying agencies upon which to rely for the natural improvement of a once polluted water, and the writer confesses that when he was first interested in this case he felt that it would take a good deal of evidence to convince him that the sewage of a small place like Moravia could make the trip down Lake Owasco in such time and in such manner as to dangerously affect the water of the lower end. The experiments which Mr. Ackerman made with reference to the relation between wind velocity and water movement in this particular case has modified my views

considerably, and I have been also impressed by the evidence shown that there is every opportunity for infected sewage material to accumulate in large frozen masses upon the ice of the inlet stream and along its shores and be thence transported either in state of suspension in the water or by being actually ferried upon cakes of ice down to the point of the Auburn intake within a period of about three days. This interval of time is short enough, of course, to allow typhoid bacteria to make the trip alive, especially so, as the water of the lake is cold; and Houston has shown that water under 50 degrees is conducive to the longevity of the typhoid germ. In support of the evidence that infected material can be so transported, the typhoid charts of the city of Auburn show an increase of the disease yearly at the time of the spring breakup.

All of this certainly goes to show that we should be cautious about banking too strongly upon the efficiency of lake purification under all circumstances, and it demonstrates the necessity of our being well acquainted with the conditions surrounding each individual case before venturing an opinion on the matter.

Mr. C. E. A. Winslow (by letter): The action brought by the People of the State of New York against the Board of Education of the town of Moravia is one of the most interesting water pollution cases of which the writer has ever had knowledge. It is unique in at least two respects. The first is that a criminal indictment was found against a board of trustees for stream pollution, under an act which makes the maintenance of a nuisance a misdemeanor and defines a nuisance as any act which "annoys, injures or endangers the comfort, repose, health or safety of any considerable number of persons." This is an example which will perhaps open the eyes of many water works officials as to a possible method of dealing with persistent and dangerous sources of pollution which may often prove more salutary than the slower processes of civil law.

The other point of special interest involved is the fact that in this instance typhoid bacilli were apparently carried in virulent condition by currents induced by wind down a lake ten miles long.

The story is in many respects a simple one. A High School of 300 pupils, in a village not yet awakened to a sense of sanitary decency, discharged and still discharges its sewage from a four inch sewer on the bank of a stream at a point which at times of low flow may be fifteen feet from the water. Here a pile of excrement

amounting to several bushels a week piles up until a flood or a thaw washes it down by way of a swift stream four miles long to the head of Owasco Lake. The danger from such a condition to the village of Moravia itself, particularly from fly transmission, and to the summer population at the head of the lake, from pollution of the water, which they may drink at times and in which they bathe constantly, is too obvious to require comment. Both in respect to the amount of fecal material and its exposure on an open bank, the pollution is of an altogether different nature from that caused by the sink drains and privy vaults incident to the normal uses of ordinary rural populations. Special danger lies too in the number of persons contributing pollution, as well as in the mere amount of excreta, since it is specific infection which is to be feared and since in a population of 300 school children we may fairly expect to find one or more typhoid carriers at any given time.

The danger to the inhabitants of Auburn from drinking the water of Owasco Lake at its lower end, after storage in a reservoir of 200,000 million gallons capacity, might seem much more problematical. Without a knowledge of the detailed facts brought out in Mr. Ackerman's investigation, many sanitarians would probably have held that the transmission of disease under such conditions would be almost an impossibility. In view, however, of his elaborate and painstaking experiments, it seems certain that with a favoring wind a surface current is produced which would carry infectious material from the head to the foot of the lake in from two to three days. Furthermore his anemometer records show that this particular wind (a southerly one) is just the one which blows steadily for the longest continuous periods. In connection with the experiments which have shown that a large proportion of typhoid bacilli will survive in water for such a period, it seems certain that the High School at Moravia constitutes a serious menace to the Auburn water supply.

The striking bacterial charts which Mr. Ackerman has displayed show that while the Auburn water is generally of good quality it is subject to a regular seasonal contamination of considerable extent during the spring months. It may be noted that this contamination is more clearly manifested by the total count of bacteria than by the colon test and the writer has wondered, in studying these charts, whether the Germans are perhaps not partly right in accusing us of "setting B. coli on a high throne and dancing before it" while we neglect the lessons of the total count. These high numbers in the

spring do not, of course, indicate any certain and necessary danger. They include all the bacteria of all sorts washed into the reservoir with the melting snow. Wherever such contamination enters a water, however, the chance of specific infection being carried in with it is always a considerable one.

A waterborne epidemic requires the coincidence of several different conditions which are fortunately not always present at the same time. In this particular instance they happened all to exist simultaneously in the spring of 1908. During the winter there was an epidemic of typhoid fever at Moravia which included at least four pupils in the High School, at least one of whom returned to school as a convalescent and very possibly as a carrier. During and after the epidemic, excreta from Moravia entered the stream at various points and in particular accumulated at the mouth of the High School sewer. In March the ice in the lake broke up and a thaw washed contaminating material of all sorts from the banks into stream and lake. The south wind blew and produced its surface currents. Within the next few weeks Auburn suffered from a typical waterborne epidemic of typhoid fever which resulted in twelve deaths and must have included at least a hundred cases. The evidence is overwheming that this epidemic was due to pollution of the waters of Lake Owasco,—and probably to pollution from Moravia since specific typhoid infection is not known to have reached tributaries of the Lake at any other point. Within the town of Moravia the High School sewer is the most dangerous single source of specific infection which careful study has brought to light.

Our interpretation of this instructive epidemic, however, rests in the last analysis on Mr. Ackerman's flow measurements and it is these measurements which constitute the really notable feature of the case. It is not too much to say that his exact and careful study of the velocity of wind-induced currents opens a new chapter in limnology and is a contribution of the first moment to the art of water supply sanitation.

SUPPORT AND AID TO HEALTH OFFICERS

By H. F. Dunham

Legislation in all, or nearly all, of our states has established a local office of great importance to towns and cities, namely, the office which is filled by the health officer. The method of selection or election varies, but it may be said in general that it serves to secure for the office a trained, well educated physician in ability above the average of his profession.

The work required or expected of him is extensive, and the opportunity exists to add to that measure of work a large amount that is no less valuable because it is neither required nor expected. Just as far as his insight, good judgment and the support extended to him warrants does he become a factor in the sanitary affairs of his city. It would be very conservative to say that the opportunities of the office should enable him to more than double his helpful influence in the community. It is a field in which executive ability, as well as medical knowledge and skill is required and should be appreciated.

Questions in great variety have to be considered, a contagious disease, proper drainage, ill arranged tenements, matters of water supply, of quarantine, of pollution of streams and the like. These take up time and service that is but poorly requited. In this wider field where no one individual can master all the technical branches legislation has offered further assistance. It recognizes the different departments of science. It provides a way to reach the chemist with cases of poisoning or with an unsatisfactory sewage effluent and the bacteriologist or biologist with samples of water, or the experienced builder with questions of construction. In such legislation, and its more or less effective embodiment in men and rules and deeds, rests the support of the health officer. That the support should be accurate or timely or beneficial in all cases must not be expected. From a number of instances of apparent failure two or three may be cited as illustrations:

1. A sample of water from gravel beds below a limited drainage area was referred by the health officer for evidence of pollution from

a known source to further certain interests connected with public welfare. The returns were to the effect that the water was not entirely satisfactory but the source of pollution was so far away that no harm could be expected from it. The practical health officer understood that terrestrial distances should be measured on the earth's surface rather than in a water bottle.

2. Several samples of water from which careful planting on gelatine when taken showed few bacteria, were sent away by a health officer and brought returns by telegram as follows: "Water full of typhoid and coli germs. Have it boiled." When the formal certificate was received it read "Full of suspected typhoid, etc." The word "suspected" being interlined evidently in another handwriting, and the certificate contained data from the most searching test perhaps known for such germs, and was marked "Negative" for all samples. And in the city where the water was very generally used, there had not been a death from typhoid fever for more than a year, nor was there any increase in the number of cases following the dispatch.

3. A third and different incident occurred where water from deep wells in a widely known formation valued for the quality of its supply was reported upon to the health officer, let us say in this wise respecting dates: "Collected on the second; received on the third; reported on the eleventh; sanitary analysis."—(All that could be desired.) "B. coli in all samples in one or ten c.c." But this important information only reached the health officer upon entreaty the following month or twenty days later.

Time was, within the memory of the members of this association, when a sample of water could be sent out perhaps to members of this association, now deceased, or retired, with the confident expectation that the samples would receive attention within a reasonable time from a thoughtful investigator who would make a valued report and charged therefor a reasonable fee. But now the fee has gone, or been reduced to express charges, the report has been sadly abbreviated, the time has been greatly extended, and the investigator? has he been modified by legislation, and has his laboratory been changed into a species of shop upon which the health officer must rely?

Questions like these may be asked, but to present them in the form of criticism is not the object of this paper, except so far as to make the real purpose apparent. Papers before this Association are open for discussion and it is the author's wish that from all sides

may come so many reports of satisfactory work under the changed conditions that the only inference possible shall involve some queer law of segregation, by which all of the errors from the entire field have come into his very limited experience.

DISCUSSION

Mr. Charles N. Kinney: The health officer needs a good deal of backing up. We have had a great deal of trouble in the state of Iowa with the enforcement of the health laws. The health officer does not feel that he has the backing of the municipal officers. The work is comparatively new in our state, and while it has the moral support of the citizens of the community, it has not sufficient support from the municipal officers. A campaign of education is necessary before the health officer will receive as full and forcible backing up as he ought to have. The work is increasing considerably in our state, and most all of the local boards of health now are falling in line with the State Board and the local officers are having less and less trouble.

President Gwinn: In former years the average water works man had the impression that the State Board of Health had a special ax sharpened that he carried around to chop off the heads of the water works people; but we have been learning a new lesson and we are now ready to be regulated any time by any intelligent regulating board, because we think it is good for us and good for the people. That applies to Boards of Health as well as all other boards.

Prof. Edward Bartow: If the State Board of Health or state officers who have supervision of the quality of water can obtain the coöperation of the water works men, a great deal will be accomplished in promoting the public health. The Water Survey of Illinois is greatly indebted to the Illinois Water Supply Association and to the water works men of the state for their support during the last five or six years. They have supported the work of the Survey and also have gone before the legislature and obtained appropriations with which to extend the work.

President Gwinn: The Indiana State Board of Health has been of great assistance in breaking down barriers between itself

and the water works people. The latter are getting acquainted with the State Board of Health, and they find that the officers do not wear horns but that, like water works people, they are trying to do the best they can for the good of all the people. By working together we will accomplish a great deal of good.

Mr. John Gaub (by letter): Mr. Dunham's paper presents several interesting facts of which the writer wishes to consider one—the rendering of an opinion as to the potability of a water. In order to condemn a water the analyst is forced to make a summation of verdicts, both quantitatively and qualitatively, and should watch the quality of the water from time to time; hence one sample is usually insufficient.

Generally liquid enrichment methods are used to test for the presence of the colon bacillus. With the use of these methods it is possible to isolate several varieties of colon, irrespective of any fluctuation in the hygienic quality of the water.

Hence with these chances it appears essential that some qualitative test characteristics of human excremental pollution be chosen, so that it will exclude many of the gas-forming coli-like organisms which are not of recent fecal origin.

In the mind of the writer the following questions present themselves: (a) What is the true object of a water analysis? (b) Should the analyst report that the water is safe? (c) Is it within his realm to report or predict what might happen in the future, from his findings; or, should he just report, and give no opinion?

To-day, there are many tests which may be used by the analyst, and each of which in its turn will assist him in rendering a verdict. But to choose only one or two of them appears somewhat dubious, when in reality plates of agar and gelatine should be made, together with gas production in dextrose and lactose, nitrate reduction and several other tests.

This question of rendering an opinion can be compared with the rendering of a diagnosis in a case of illness. Should the physician fail or err in his judgement, he becomes charged with incompetency, and in severe cases with malpractice, whereas in the case of the water analyst, the analyst justifies himself by saying that he used "standard methods" which may in some cases be applicable to the problem, and in some may not give sufficient data for the rendering of a true opinion. Hence in the case of the physician the health

of one is at stake, while in the case of the water analyst, the health of a community.

Hence it appears self-evident that some sort of information, and that the fullest, should be forthcoming from an analyst when given some water to diagnose as to its potability, and this information can only be obtained by considering the problem as a water problem, just as the engineer considers the building of a railroad.

THE BACTERIA COUNT ON GELATIN AND AGAR MEDIA AND ITS VALUE IN CONTROLLING THE OPERATION OF WATER PURIFICATION PLANTS

By James M. Caird

There are very few water purification plants in operation in this country that do not have some method of control in their operation. Some use the removal of turbidity and color as the guide; others use the bacterial removal as the standard for the operation and its use has proved to be of the utmost value.

All water purification plants should be tested every day, but owing to the expense, the smaller plants are unable to do this. These latter have tests made two or three times a year in order to keep them under control.

The use of gelatin culture media to determine the number of bacteria in water has been of great value. Because of its composition a greater variety of organisms will develop on this medium than on others.

In 1892 the German Imperial Board of Health issued rules to control the operation of water purification plants somewhat as follows: The culture media to be used in growing the bacteria was to be gelatin, incubated at 20 degrees Centigrade for 48 hours. The effluent from filters should not contain over 100 bacteria per c.c. and the bacterial content was to be as much lower as it was possible to obtain.

The report of the Committee on Standard Methods of Water Analysis to the Laboratory Section of the American Public Health Association, 1905, states:

> The standard medium for determining the number of bacteria in water shall be nutrient gelatin, as is the case in Germany and England. If any medium other than standard gelatin is used, this fact shall be stated in the report.

This medium, gelatin, has always been considered the standard and has been in use at most water purification plants until the

revised report of the Committee on Standard Methods of Water Analysis American Public Health Association, 1912, recommended that:

> Since gelatin does not give the total number of bacteria in the water, the committee has thought it wise to use agar incubated at 37 degrees Centigrade as a standard medium. This admits of counts in one day instead of two, and gives results on the kind of bacteria growing at blood temperature and therefore more nearly related to pathogenic types.

As the number of pathogenic bacteria in water are relatively small compared with the ordinary "water bacteria," and incubation at a temperature of 37 degrees Centigrade, while preventing the growth of a large number, does not eliminate all of the water bacteria and, therefore, is likely to lead to incorrect interpretation of results.

While the use of agar at 37 degrees Centigrade permits of counts in 24 hours, the presumptive test for B. Coli communis gives results of far greater value in the same length of time.

It is also fair to assume that filtration removes all classes of bacteria in about the same proportion, and any medium which will permit of the growth of the greatest variety of bacteria is the most valuable in testing the efficiency of a purification plant.

The writer has caused special investigations to be made at several purification plants in order to learn the comparative results obtained by the gelatin and agar media.

BANGOR, MAINE

The water supply of Bangor, Maine, is obtained from the Penobscot River, the drainage area of which is 7700 square miles above the intake. The water is always highly colored and contains very little turbidity. Waste from the pulp mills and sewage enters the river at several places.

The water passes through a coagulation basin, after which it is filtered by the American Gravity Process. The filtered water is stored in covered reservoirs until delivered to the consumers.

Table Showing Comparative Bacterial Counts and Percentage of Positive Presumptive Tests for B. Coli communis, Bangor, Maine

	GELATIN 20° C. 48 HOURS	AGAR 20° C. 48 HOURS	AGAR 37° C. 24 HOURS	B. COLI-COMMUNIS
Raw	3,057.	677.	139.	76.60%
Basin	600.	157.	28.	00.00%
Filtered	20.	15.	7.	00.00%
City Tap	12.	7.	5.	00.00%

Table Showing Efficiency of Plant by Different Media, Bangor, Maine

BACTERIA REMOVED BY	GELATIN 20° C. 48 HOURS	AGAR 20° C. 48 HOURS	AGAR 37° C. 24 HOURS	B. COLI-PRESUMPTIVE TEST
Basin	80.38%	76.81%	79.86%	100.00%
Filters	96.66%	90.45%	75.00%	
Total	99.35%	97.79%	94.97%	
Flt. to Tap	40.00%	53.34%	28.51%	

Table Showing the Percentage of Bacteria not Developing on Agar, Bangor, Maine

	GELATIN TO AGAR 20°	AGAR 20° TO AGAR 37°	GELATIN 20° TO AGAR 37°
Raw	77.86%	79.47%	95.46%
Basin	73.84%	82.17%	95.34%
Filtered	25.00%	53.34%	65.00%
City Tap	41.67%	28.57%	58.34%

Sulphate of alumina is used as a coagulant; lime water is used to make up the deficiency in alkalinity, but no calcium hypochlorite is used at Bangor, Maine.

HARRISBURG, PENNSYLVANIA

The water supply of Harrisburg, Pennsylvania, is obtained from the Susquehanna River which has a drainage area of about 24,000 square miles above the intake.

The water is pumped to a settling basin, sulphate of alumina and calcium hypochlorite being added before it enters this basin. From the basin the water flows by gravity to the filters, American Gravity Type, after which it is stored in an uncovered reservoir.

Table Showing Comparative Bacterial Counts and Percentage of Positive Presumptive Tests for B. Coli communis, Harrisburg, Pennsylvania

SOURCE	GELATIN 20° C. 48 HOURS	AGAR 20° C. 48 HOURS	AGAR 37° C. 24 HOURS	B. COLI-COMMUNIS
Raw	3,511.	1,451.	404.	45.12%
Basin	44.	24.	15	
Filtered	2.2	1.2	1.9[1]	1.70%
City Tap	.....21.	11.2	6 5	5.79%

Because of the low number of bacteria in the filtered and tap waters the results are expressed including the first decimal place in the averages.

Table Showing Efficiency of Plant by Different Media, Harrisburg, Pennsylvania

	GELATIN 20° C. 48 HOURS	AGAR 20° C. 48 HOURS	AGAR 37° C. 24 HOURS	B. COLI-PRESUMPTIVE
Basins	98.75%	99.35%	96.29%	
Filters	95.00%	95.00%	87.34%	
Total	99.94%	99.92%	99.53%	96.24%
City Tap	854.54%[2]	833.33%[2]	242.10%[2]	240.58%[2]

Table Showing the Percentage of Bacteria not Developing on Agar, Harrisburg, Pennsylvania

	GELATIN TO AGAR 20° C.	AGAR 20° TO AGAR 37°	GELATIN 20° TO AGAR 37°
Raw	58.68%	72.16%	88.47%
Basin	45.46%	37 50%	65.91%
Filtered	45.46%	58.33%[3]	13.64%
City Tap	46 67%	41.97%	96.05%

SUNBURY, PENNSYLVANIA

The water supply of Sunbury, Pennsylvania, is obtained from the Little Shamokin Creek. This is first stored in large settling reservoirs, after which it is pumped to the coagulation basins, sulphate of alumina being used as a coagulant, from whence it flows by gravity to the filters which are of the American Gravity Type.

The color and turbidity of the water, after passing through the settling reservoirs is low. No hypochlorite is used at this plant.

[1] In order to obtain any count it was necessary to incubate for 48 hours.

[2] Increase.

[3] Increase due to 48 hours' incubation.

Table Showing Comparative Bacterial Counts and Percentage of Positive Presumptive Tests for B. Coli communis, Sunbury, Pennsylvania

	GELATIN 20° C. 48 HOURS	AGAR 20° C. 48 HOURS	AGAR 37° C. 24 HOURS	B. COLI-COMMUNIS
Unfiltered	550.	350.	250.	20.00%
Basin	90.	40.	35.	00.00%
Filtered	12.	4.	2.	00.00%

Table Showing Efficiency of Plant by Different Media, Sunbury, Pennsylvania

	GELATIN 20° C. 48 HOURS	AGAR 20° C. 48 HOURS	AGAR 37° C. 24 HOURS	B. COLI-PRESUMPTIVE
Basins	83.64%	88.58%	86.00%	100.00%
Filters	86.67%	90.00%	91.12%	
Total	97.82%	98.86%	99.20%	

Table Showing the Percentage of Bacteria not Developing on Agar, Sunbury, Pennsylvania

	GELATIN TO AGAR 20° C.	AGAR 20° C. TO AGAR 37° C.	GELATIN 20° C. TO AGAR 37° C.
Unfiltered	36.37%	28.58%	54.55%
Basin	55.56%	12.50%	60.01%
Filtered	66.67%	50.00%	83.34%

WILKINSBURG, PENNSYLVANIA

The water supply of the Pennsylvania Water Company is obtained from filter cribs located in the Allegheny River. This water is a mixture of "ground water" and filtered river water, to which is added, at times, water direct from the river.

The water is pumped to a coagulation basin, after which it passes through filters of the American Gravity Type and is stored in an open reservoir.

Table Showing Comparative Bacterial Counts and Percentage of Positive Presumptive Tests for B. Coli communis, Wilkinsburg, Pennsylvania

	GELATIN 20° C. 48 HOURS	AGAR 20° C. 48 HOURS	AGAR 37° C. 24 HOURS	B. COLI-COMMUNIS
River	5,900.	2,780.	975.	100.00%
Untreated	4,788.	1 935.	955.	49.27%
Settled	2,693.	1,200.	483.	
Filtered	15.	3.	0.4	1.14%
City Tap	37.	6.	0.5	00.00%

Table Showing Efficiency of Plant by Different Media, Wilkinsburg, Pennsylvania

BACTERIA REMOVED BY	GELATIN 20° C. 48 HOURS	AGAR 20° C. 48 HOURS	AGAR 37° C. 24 HOURS	B. COLI-PRESUMPTIVE TEST
Cribs	18.85%	30.40%	2.06%	50.73%
Basin	43.76%	37.99%	49.43%	
Filters	99.45%	99.75%	99.92%	97.69%
Unfiltered to Filtered	99.69%	99.85%	99.96%	
Total R to F.	99.75%	99.90%	99.95%	98.86%
City Tap	146.66%[1]	100.00%[1]	25.00%	100.dec.

Table Showing the Percentage of Bacteria not Developing on Agar, Wilkinsburg, Pennsylvania

	GELATIN TO AGAR 20° C.	AGAR 20° C. TO AGAR 37° C.	GELATIN 20° C. TO AGAR 37° C.
River	52.89%	64.93%	83.13%
Untreated	59.59%	50.65%	80.06%
Settled	55.44%	59.75%	82.07%
Filtered	80.00%	98.67%	97.34%
City Tap	83.79%	91.67%	98.65%

Sulphate of alumina is used as a coagulant and is applied to the water before it enters the settling basin.

Calcium hypochlorite is added to the water after it passes the basin and before it enters the top of the filters.

WILMINGTON, DELAWARE

The water supply of Wilmington, Delaware, is obtained from the Brandywine Creek, which has a drainage area of about 320 square miles above the intake.

The method of treatment is as follows: the water flows by gravity to the preliminary filters; after passing these filters it flows by gravity to the pumps from whence it is delivered to the settling reservoir; after passing through this reservoir it flows by gravity to the final, English or Slow Sand filters, and then is delivered to the consumers, part of the supply first passing through an open reservoir to the Low Service Tap.

[1] Increase.

Table Showing Comparative Bacterial Counts and Percentage of Positive Presumptive Tests for B. Coli communis, Wilmington, Delaware

	GELATIN 20° C. 48 HOURS	AGAR 20° C. 48 HOURS	AGAR 37° C. 24 HOURS	B. COLI-PRESUMPTIVE TEST
Creek	7,393.	4,528.	4,076.	94.96%
Pre-filt	4,812.	3,032.	2,548.	84.36%
Settled	2,612.	1,209.	756.	78.18%
Effluent	27.	15.	12.	4.29%
H. S. Tap	34.	18.	14.	3.58%
L. S. Tap	199.	92.	75.	5.63%

Table Showing Efficiency of Plant by Different Media, Wilmington, Delaware

	GELATIN 20° C. 48 HOURS	AGAR 20° C. 48 HOURS	AGAR 37° C. 24 HOURS	B. COLI-PRESUMPTIVE TEST
Pre-Filts	34.92%	33.04%	37.49%	11.17%
Basin	45.72%	60.13%	70.33%	7.33%
Final Filts	98.97%	98.76%	98.42%	94.52%
Total	99.64%	99.67%	99.91%	95.38%
F. F. to H. S. T.	25.92%[1]	20.00%[1]	14.28%[1]	16.55% dec.
F. F. to L. S. T.	637.03%[1]	513.33%[1]	533.33%[1]	57.26%[1]

Table Showing the Percentage of Bacteria not Developing on Agar, Wilmington, Delaware

	GELATIN TO AGAR 20° C.	AGAR 20° C. TO AGAR 37° C.	GELATIN 20° C. TO AGAR 37° C.
Creek	38.78%	9.99%	44.87%
Pre-Filt	36.99%	15.97%	47.05%
Settled	53.72%	37.47%	71.06%
Effluent	44.45%	20.00%	55.56%
H. S. T.	47.06%	22.23%	58.83%
L. S. T.	53.77%	17.40%	61.81%

This water was not treated with any coagulants or sterilizing solutions at the time these investigations were made.

ROCHESTER & LAKE ONTARIO WATER CO., ROCHESTER, N. Y.

The water supply of the Rochester and Lake Ontario Water Company, is obtained from Lake Ontario. The intake extends 4000 feet from the shore and is about 1¼ miles west of the lighthouse on the pier at the mouth of the Genesee River.

The water is pumped to a settling basin where it is treated with

[1] Increase.

sulphate of alumina and calcium hypochlorite after which it passes through pressure filters to the consumers.

Table Showing Comparative Bacterial Counts and Percentage of Positive Presumptive Tests for B. Coli communis, Rochester, New York

	GELATIN 20° C. 48 HOURS	AGAR 20° C. 48 HOURS	AGAR 37° C. 24 HOURS	B. COLI-PRESUMPTIVE TEST
Raw	6,422.	3,068.	690.	33.33%
Settled	52.	25.	20.	2.02%
Filtered	8.	5.	5.	00.00%

Table Showing Efficiency of Plant by Different Media, Rochester, New York

	GELATIN 20° C. 48 HOURS	AGAR 20° C. 48 HOURS	AGAR 37° C. 24 HOURS	B. COLI-PRESUMPTIVE TEST
Basin	99.19%	99.19%	97.11%	93.94%
Filters	84.62%	80.00%	75.00%	100.00%
Total	99.88%	99.84%	99.28%	100.00%

Table Showing the Percentage of Bacteria not Developing on Agar, Rochester, New York

	GELATIN TO AGAR 20° C.	AGAR 20° C. TO AGAR 37° C.	GELATIN 20° C. TO AGAR 37° C.
Raw	52.23%	77.55%	89.26%
Settled	48.07%	20.00%	61.54%
Filtered	37.50%	00.00%	37.50%

Owing to legal and other reasons it is necessary to cite the following cases by numbers.

CASE NUMBER ONE

This water supply is obtained from wells. The water contains considerable iron and manganese, and is passed through American Gravity Type Filters, sulphate of alumina being used as a coagulant.

Table Showing Comparative Bacterial Counts and Percentage of Positive Presumptive Tests for B. Coli communis, Case No. 1

	GELATIN 20° C. 48 HOURS	AGAR 20° C. 48 HOURS	AGAR 37° C. 24 HOURS	B. COLI-PRESUMPTIVE TEST
Raw	190.	43.	8.	20.00%
Filtered	135.	27.	6.	00.00%

Table Showing Efficiency of Plant by Different Media, Case No. 1

	GELATIN 20° C. 48 HOURS	AGAR 20° C. 48 HOURS	AGAR 37° C. 24 HOURS	B. COLI-PRESUMPTIVE TEST
Filters	28.95%	37.21%	25.00%	100.00%

At the time this test was made only sufficient sulphate of alumina to remove the color was being applied.

Table Showing the Percentage of Bacteria not Developing on Agar, Case No. 1

	GELATIN TO AGAR 20° C.	AGAR 20° C. TO AGAR 37° C.	GELATIN 20° C. TO AGAR 37° C.
Raw	77.37%	81.40%	95.79%
Filtered	80.00%	77.78%	95.56%

CASE NUMBER TWO

This water supply is obtained from a polluted river. The water is filtered through American Type Gravity Filters, sufficient sulphate of alumina being used to remove the color and turbidity and calcium hypochlorite is added to the filtered water.

Table Showing Comparative Bacterial Counts and Percentage of Positive Presumptive Tests for B. Coli communis, Case No. 2

	GELATIN 20° C. 48 HOURS	AGAR 20° C. 48 HOURS	AGAR 37° C. 24 HOURS	B. COLI-PRESUMPTIVE TEST
Raw	42,516.	18,950.	2,916.	100.00%
Basin	19,200.	4,216.	1,600.	93.33%
Filtered	3,408.	1,378.	191.	46.66%
Tap	712.	270.	41.	26.66%

It is to be noted that the basins removed 54.85 per cent of the bacteria, gelatin count, and that 93.33 per cent of the one c.c. samples examined for B. Coli communis gave positive results.

Table Showing Efficiency of Plant by Different Media, Case No. 2

	GELATIN 20° C. 48 HOURS	AGAR 20° C. 48 HOURS	AGAR 37° C. 24 HOURS	B. COLI-PRESUMPTIVE TEST
Basin	54.85%	77.76%	45.13%	6.67%
Filters	82.25%	67.32%	88.07%	50.01%
Hypo	79.11%	80.41%	77.39%	42.87%
Total	98.33%	98.58%	98.60%	73.34% plus

Table Showing the Percentage of Bacteria not Developing on Agar, Case No. 2

	GELATIN TO AGAR 20° C.	AGAR 20° C. TO AGAR 37° C.	GELATIN 20° C. TO AGAR 37° C.
Raw	55.43%	84.62%	93.15%
Basin	78.05%	62.05%	91.67%
Filtered	59.57%	86.14%	94.40%
Tap	62.08%	84.82%	94.25%

CASE NUMBER THREE

This water supply is obtained from storage reservoirs located in the mountains. These reservoirs have a total drainage area of about 33 square miles, and a population on the watershed of about 25 per square mile.

The city is divided into two distinct systems, known as the High and Low Pressure.

Before being delivered to the consumer, the water passes through Pressure Type American Filters. Each system has its independent supply and filters.

At times these filters are operated beyond their rated capacity, and because of the local conditions it is necessary to wash them with unfiltered water.

Table Showing Comparative Bacterial Counts and Percentage of Positive Presumptive Tests for B. Coli communis, Case No. 3

	GELATIN 20° C. 48 HOURS	AGAR 20° C. 48 HOURS	AGAR 37° C. 24 HOURS	B. COLI-PRESUMPTIVE TEST
Raw H. P.	3,142.	1,066.	166.	75.86%
Raw L. P.	4,319.	1,082.	357.	75.86%
Filt. H. P.	255.	79.	12.	4.13%
Filt. L. P.	530.	211.	69.	8.96%

Table Showing Efficiency of Plant by Different Media, Case No. 3

	GELATIN 20° C. 48 HOURS	AGAR 20° C. 48 HOURS	AGAR 37° C. 24 HOURS	B. COLI-PRESUMPTIVE TEST
H. P. Filt.	91.89%	92.59%	92.78%	94.56%
L. P. Filt.	87.73%	88.61%	80.68%	88.19%

Table Showing the Percentage of Bacteria not Developing on Agar, Case No. 3

	GELATIN TO AGAR 20° C.	AGAR 20° C. TO AGAR 37° C.	GELATIN 20° C. TO AGAR 37° C.
Raw H. P.	66.08%	84.43%	94.72%
Filt. H. P.	69.02%	84.81%	95.30%
Raw L. P.	57.12%	80.74%	92.74%
Filt. L. P.	60.19%	68.30%	86.98%

Crystal alum is used as the coagulent; no calcium hypochlorite is used.

CASE NUMBER FOUR

This supply is obtained from a creek which is somewhat polluted. The water is pumped through an aerator on its way to the settling basins. Calcium hypochlorite is added at the pumping station. After passing through the settling basins it flows by gravity, sulphate of alumina being applied, to American Filters, Gravity Type, and after filtration is stored in covered reservoirs.

Table Showing Comparative Bacterial Counts and Percentage of Positive Presumptive Tests for B. Coli communis, Case No. 4

	GELATIN 20° C. 48 HOURS	AGAR 20° C. 48 HOURS	AGAR 37° C. 24 HOURS	B. COLI-PRESUMPTIVE TEST
Creek	15,033.	8,900.	3,533.	100.00%
Aerator	1,578.	890.	580.	36.00%
Basins	1,180.	564.	274.	56.66%
Filtered	147.	38.	16.	8.88%
City Tap	133.	21.	7.	3.33%

At the time these investigations were made it was known that the filters were not working properly. The gelatin count was high, but the agar count at 37 degrees was not high; if agar had been used as the medium, the trouble could not have been located.

Table Showing Efficiency of Plant by Different Media, Case No. 4

	GELATIN 20° C. 48 HOURS	AGAR 20° C. 48 HOURS	AGAR 37° C. 24 HOURS	B. COLI-PRESUMPTIVE TEST
Hypo	89.51%	90.00%	83.59%	74.00%
Basins	25.23%	36.63%	52.76%	57.38% inc.
Filters	87.54%	93.27%	94.17%	84.33%
Total	99.03%	99.58%	99.52%	91.12 plus

The water is from seven to ten days in passing through the settling basins.

Table Showing the Percentage of Bacteria not Developing on Agar, Case No. 4

	GELATIN TO AGAR 20° C.	AGAR 20° C. TO AGAR 37° C.	GELATIN 20° C. TO AGAR 37° C.
Creek	40.78%	70.31%	76.50%
Aerator	43.60%	34.83%	63.31%
Basins	52.15%	51.42%	76 78%
Filtered	74.15%	57.90%	89.12%
City Tap	84.22%	66.67%	94.74%

CASE NUMBER FIVE

This supply is obtained from a polluted river. The filter plant has been rebuilt; this test was started before exact working conditions were known.

The water is passed through a coagulation basin, sulphate of alumina being used as a coagulant, and then through filters of the American Gravity Type. During the later part of this investigation calcium hypochlorite was added to the filtered water.

Table Showing Comparative Bacterial Counts and Percentage of Positive Presumptive Tests for B. Coli communis, Case No. 5

	GELATIN 20° C. 48 HOURS	AGAR 20° C. 48 HOURS	AGAR 37° C. 24 HOURS	B. COLI-PRESUMPTIVE TEST
Raw	49,056.	29,481.	23,843.	100.00%
Basin	24,797.	16,167.	12,288.	100.00%
Filtered	3,690.	2,595.	2,027.	96.91%
City Tap	233.	132.	89.	18.94%

It is to be noted that the filtered water count by agar at 37 degrees Centigrade was less than 100 per c.c., yet 18.94 per cent of the 1 c.c. samples examined for B. Coli communis gave positive results.

Some idea of the quality of the river water may be gained from the fact that while the basin and filters removed 92.48 per cent of the bacteria, gelatin count, B. Coli communis was present in 96.91 per cent of the 1 c.c. samples examined.

Table Showing Efficiency of Plant by Different Media, Case No. 5

	GELATIN 20° C. 48 HOURS	AGAR 20° C. 48 HOURS	AGAR 37° C. 24 HOURS	B. COLI-PRESUMPTIVE TEST
Basin	49.46%	45.17%	48.47%	
Filters	85.08%	83.95%	83.51%	3 09%
Hypo	93.69%	94.92%	95.61%	80.36%
Total	99.53%	99.66%	99.63%	81.06%

Table Showing the Percentage of Bacteria not Developing on Agar, Case N . 5

	GELATIN TO AGAR 20° C.	AGAR 20° C. TO AGAR 37° C.	GELATIN 20° C. TO AGAR 37° .
Raw	39.91%	19.37%	52.40%
Basin	34.81%	24.00%	50.49%
Filtered	29.68%	21.89%	45.07%
City Tap	43 35%	32.58%	61.81%

It is not the writer's intention to claim that the agar counts are of no value as this method has been used by him for special investigations for many years.

In the testing of filtration plants it has been found that if agar at 37 degrees Centigrade is used as the medium, results in a large number of cases would indicate that the efficiency was 100 per cent, and this is surely not a correct statement.

It has also been found in examining some spring waters that the agar plates were sterile, while the gelatin plates showed quite a number of organisms.

If agar plates are used alone it is quite possible that incorrect deductions are likely to be made.

In using agar it is very necessary that it be cooled to the proper temperature before mixing with the water, otherwise a too high

temperature might result in the death of some organisms that would otherwise develop.

It has been argued that by using agar at 37 degrees Centigrade, only one incubator is necessary for a laboratory equipment. In all well equipped laboratories it is necessary to have an ice chest or refrigerator; the additional cost for a 20 degree Centigrade incubator with regulator should not exceed $100.

Professor G. C. Whipple recently wrote to "twenty of the leading filter operators," receiving replies from eighteen. Of these eleven or 61 per cent preferred the 20 degree Centigrade gelatin counts; 4 or 22 per cent the agar at 37 degrees Centigrade; while 3 or 16.7 per cent withheld opinions until further investigation.

From personal investigations it appears that the people who are most desirous to use the agar 37 degree Centigrade counts are those who have filtered water and get gelatin counts above 100 per c.c.

The results given in this paper cover periods from six days to one year and are the averages. It would require too much space to include the daily results of all of these tests.

From the results obtained it seems to the writer advisable to continue basing the efficiency of water purification plants on the gelatin counts, which require 48 hours incubation, together with the presumptive tests for B. Coli communis from which fairly accurate results can be obtained in 24 hours.

In closing the writer wishes to express his appreciation of the work of his assistants at the various plants where these tests were conducted.

The writer does not wish to be understood as not favoring agar media, for he uses it for special purposes, but for regular work does not think the agar media is the best.

DISCUSSION

Mr. D. D. Jackson: There has been considerable discussion, particularly by members of the American Public Health Association, regarding standard media; and the present standard media of agar at 37 degrees is unsatisfactory to a great many men who are engaged in filter work; in other words, they do not get the same percentage of reduction on agar that they do on gelatin. An attempt has been made to establish one standard which can be used particularly in local work as representing the sanitary con-

ditions of the water. In the work which we carried on covering a great many thousands of samples, we found that the agar of 37 degrees as used with various waters represents in a very general way the sanitary condition of the water. At the same time, in tests of filter plants where the count is so low as it is with the agar at 37 degrees, the relative percentage of reduction which is always wanted in such cases does not show up so well. The speaker is inclined to believe that it would be wise to indorse the use of both of these standards as the laboratory man sees fit to employ them. In a local case where one standard is to be used for local purposes perhaps the agar at 37 degrees would be wisest, if we have to use one standard; but in taking tests of sterilization in water in those waters which have only fifteen to twenty bacteria to start with on the agar and come down to two or three, it does not look as if the work that was being done was really the same as if you started with one thousand and came down to fifty. It is merely a practical proposition. At the same time the speaker sees no reason why water works men should be bound down to that particular standard; and it might be very wise to have the use of either of these standards in water works records optional. The idea of establishing one standard, as before stated, was to try and have all the records comparable.

Mr. James M. Caird: As the efficiencies of most filter plants have been based upon the bacterial count on gelatin it would be a great mistake to change at this time. Any change at this time would cause a great deal of confusion and results previously obtained by the gelatin method would be of little value in adjusting the operation of the plant.

The average efficiency of the plants mentioned in this paper by different media was as follows:

Gelatin 20° C. 48 hours	98.42 per cent
Agar 20° C. 48 hours	98.82 per cent
Agar 37½° C. 24 hours	99.30 per cent
Positive presumptive test for B. Coli	90.42 per cent

It is seen that when the efficiency is determined by either gelatin or agar at 20° C. 48 hours, the results are very similar. The efficiency by agar at 37½° C. 24 hours, is somewhat higher than the other methods, and is very much higher than the efficiency as determined by the positive presumptive test for B. Coli-communis.

Mr. Frederick H. Stover: At Louisville we have not adopted agar at 37 degrees as the standard media. We have made some comparative tests on the two, but scarcely feel justified from the results obtained in making so radical a change. Our practice is to use both lactose agar at 37 degrees and gelatin at twenty. We ran some comparative tests under the new method and found that the results were not all that could be desired.

The nutrient agar incubated for twenty-four hours at 37 degrees usually gave higher counts than lactose agar incubated for the same period, but its ratio to the gelatin count was rather variable and was apparently dependent on the seasonal variations of temperature.

Nutrient agar incubated for 48 hours at 20 degrees Centigrade gave results quite closely comparable to gelatin plates incubated for the same period, especially in the case of the filtered water. The use of agar in this way, at 20 degrees Centigrade, has one advantage over gelatine in that no plates are lost by liquefaction, and the colonies show less tendency to spread than when grown at 37 degrees.

The speaker is of the opinion that both a 37 degree and a 20 degree count should be used in connection with purification plants, as the extra labor involved amounts to very little in the aggregate, and is more than compensated for in the additional information gained.

Prof. Edward Bartow: Owing to the recommendation of the Committee on Standard Methods of Analysis, in their revised report*, that the count on agar media at $37\frac{1}{2}$ degrees be adopted as a standard, the State Water Survey on June 20, 1912 began a series of comparative tests. Since that date 1500 samples of water received in the regular laboratory routine have been tested for the number of bacteria growing on gelatin at 20 degrees C. and agar at $37\frac{1}{2}$ degrees C. The relation of the number of bacteria growing on gelatine to those growing on agar seemed very inconstant and in order to try to find some definite basis for comparison we have arranged the results in four classes according to the sources of the samples.

*Report of Committee on Standard Methods, American Public Health Association, 1912.

1. Untreated surface water.
   a. Mississippi River water.
   b. Water from the smaller streams.
   c. Untreated Lake Michigan water.
2. Treated surface waters.
3. Water from shallow wells.
4. Water from deep wells.

1. *Untreated Surface Water.* This class we have again divided into (a) water from the Mississippi River, (b) water from the smaller streams of the state, (c) water from Lake Michigan. Fifty samples of the raw Mississippi River water showed an average ratio of the number of bacteria growing on agar and gelatine of 1 to 2.1. The maximum was 1 to 131, the minimum 1 to 1.1. Seventy samples from the small rivers of the state, including the Sangamon, Vermilion, Fox, Rock, Kankakee and Little Wabash had a ratio of 1 to 2. Forty-five samples from Lake Michigan had a ratio of 1 to 45. The maximum was 1 to 160, the minimum 1 to 1.

2. *Treated Surface Waters.* The number of bacteria growing on the different media was more nearly equal than in the raw water. In some instances where the counts were low the count on agar exceeded the gelatin but such instances were rare. Three samples considered gave a ratio of 1 to 5. The maximum was 1 to 30, the minimum 1 to 2. Considering 6 analyses where gelatin exceeded the agar, an inverse ratio of 10 to 1 was secured. The maximum was 1 to 15, the minimum 1 to 4. This is true only of Lake Michigan water.

3. *Water From Shallow Wells.* The ratio of the number of colonies growing on agar to that on gelatin was practically the same as in raw surface water. Five hundred eighty samples considered gave a ratio of 1 to 2.5. The maximum was 1 to 25, the minimum 1 to 1. The number of bacteria growing on either media was not as high as found in the river water.

4. *Water From Deep Wells.* The results are more regular than in the preceding classes. On both media the numbers are uniformly low and are often equal but usually more colonies grow on the gelatin than on the agar. This may be due to the longer incubation period for gelatin than for agar. The ratio found from 200 samples was 1 to 25. The maximum was 1 to 40, the minimum 1 to 1.

To summarize our results it would seem that in highly polluted

waters there is a wide variation between the number of bacteria growing on the two media, and that in pure waters the number is more nearly equal and in many cases equal.

If only one media is to be used, sometimes gelatine at 20 degrees would be more satisfactory, and in other cases the agar at 37½ degrees would give all the information desired. The matter needs further consideration before any one standard should be adopted. If both could be used practically it would be better.

Mr. James M. Caird: A comparison of the results obtained by gelatin and agar when incubated at 20° C. for 48 hours, shows that in the case of the unfiltered waters the agar count was 48.90 per cent less than the gelatin and that the agar counts for the filtered waters was 61.72 per cent less than gelatin. These results show that the agar media restrict the growth of a large number of organisms. The use of the blood temperature (37½° C.) also tends to reduce the bacterial count when agar is used. In the case of the unfiltered waters the count on agar at 37½° C. 24 hours, was 46.14 per cent less than on agar at 20° C. for 48 hours. In the case of the filtered waters the agar count at 37½° C. was 67.17 per cent less than the agar at 20° C.

In the case of unfiltered waters incubated on agar at 37½° C. 24 hours, the bacterial count was 73.34 per cent less than the gelatin count at 20° C. for 48 hours. The filtered water agar count at 37½° C. was 87.43 per cent less than the gelatin count at 20° C. for 48 hours.

Mr. W. C. Lounsbury: A word about the conditions that we found in Superior concerning the agar and gelatin counts. We have made in our laboratory for some six or seven years very many determinations on our raw and filtered water. In our case the raw water is exceedingly pure, because it is derived from wells, and is filtered simply to remove the iron, not to remove bacteria. There are a few bacteria in the raw water, however, and our counts on gelatin will run from zero up to 35. Thirty-five has been the maximum count for some years. Some may think that it is not worth while to analyze this water daily for such low counts; yet as a matter of insurance it is thought worth while at Superior. For our purposes we have found in keeping track of the water that our experience shows that the count on agar alone would not be

sufficient. We define and can notice differences in the gelatin count, and if we have the agar count alone it would be of little use to us. You might say, as was just stated, that it would not seem worth while to analyze so pure a water, yet it is worth while with the gelatin count. Where the count runs from 35 to 50 we get an indication of the character of the pollution that would be lost altogether with only the agar count.

Mr. Warren U. C. Batton (by letter): The writer has read this paper with considerable interest, and believes that we should be particularly gratified that the author has been able to present to us so much data from various sources.

No doubt to many of us, the seemingly uncalled-for and hasty jump from gelatin at 20 degrees C. to agar at 37 degrees, as a standard method for making counts of bacteria in water work, as recommended by the committee of the American Public Health Association, was astounding, to say the least.

The writer has no hesitancy in saying that he was very skeptical as to the wisdom of such a move. He is none the less skeptical at the present writing. In fact he agrees quite heartily with the author of this paper in his stated conclusions. It is true that pathogenic bacteria develop well at the 37 degrees C. It is also true that there are other organisms non-pathogenic in character, and having no more specific bearing on the sanitary conditions of the water than certain similar organisms which develop on the gelatine at 20 degrees C. which also develop at 37 degrees C.

In bacterial water analysis, we have two main objects where purification is involved.

1. Is the water in a reasonably satisfactory sanitary condition?
2. How efficient is our purification process?

We should aim to obtain this information as quickly as possible, but must not sacrifice the quality of our conclusions. Inasmuch as the real sanitary test of the water, namely, the test for the colon group of organisms, is not on a strictly quantitative footing, we need some other test which is quantitative to go with it. The socalled total count answers this purpose very well. For such a count there is no doubt in the writer's mind that we should use the medium which gives the largest count and is consistent with itself. Gelatine at 20 degrees has served this purpose very well. Agar at 37 degrees does not do this and inasmuch as it does not confine itself to the pathogens or organisms of strictly sewage origin, the writer can

see no particular advantage, other than the obtaining results in 24 hours. On the other hand, of what particular value are 24 hour results that have as yet a questionable interpretation in our diagnosis?

It is true that some form of presumptive test for the colon group seems, for the present, to meet our real needs much better than 37 degree agar counts. Very serviceable indications on coli can be obtained in 24 hours.

The writer anticipates that there will be other changes in the bacterial analysis of water in the coming years.

It is not improbable that we shall come to a 72 hour or even longer count at 20 degrees on gelatin. It is possible that, after study by many observers on different waters, we shall be convinced that a 37 degree count on agar after 24 hours will be an excellent adjunct to our diagnosis when interpreted with a 72 hour count on gelatin.

It may be that we can attach some sanitary significance to the relation between the two, although the writer does not as yet see it.

For the control of purification processes, the writer can conceive no more rapid and ideal method than a simple quantitative determination of the colon group by some selective, yet sensitive medium. It is, he believes, quite possible.

In the examination of water we cannot have too many data so long as they are scientifically obtained and capable of intelligent interpretation. Data of any other character are worse than useless. In other words, it is folly to use blindly a method which does not give data which we can interpret intelligently. In our opinion, agar at 37 degrees count is in this state of uncertainty and we believe that many plant operators who have hesitated to accept it as standard procedure are justified in so doing because of meagre data on its value as compared with other tried procedures.

The writer, like the author of the paper, has been seeking information along this line. For some months he has had conducted in the laboratory, under his supervision, a series of comparative tests on all classes of water from the worst to the best which are handled as routine. He is not ready to make a statement on this work at present, as it is proposed to conduct it long enough to cover all conditions of seasonal variations and all known variations in character of the water due to the local conditions.

He has not made a critical analysis of the data as yet, but such observations as he has personally made lead to the belief that the conclusions of the author of the paper should be approved. It is

to be hoped that many others will come forward and make public data along this line as that is the only way we can progress on the question of standard methods.

Our standard methods of laboratory procedure should be held always as a keen tool in the hands of a skilled worker, and not as a goad in the hands of a driver. A distinction should be made between standard procedure and "Rule of thumb" methods for bacteriological analyses.

Thirty-seven agar counts have their functions under certain conditions but from the writer's experience, thus far, their function is not to displace gelatin for counts in water analysis, yet we may find them to be a valuable supplement.

MR. S. T. POWELL (by letter): It would indeed be unwise to substitute for gelatin culture medium any other media that tend to give a lower number of bacteria in water, irrespective of the character of the organisms that may develop. No doubt cultures grown upon agar at 37° C. are a good addition, but a poor substitute for gelatin counts for routine tests in the water laboratory.

Some time ago the writer carried on a series of experiments similar to those reported by Professor Caird. The average results obtained are shown below:

SOURCE	GELATINE 20° C. 48 HOURS	AGAR 20° C. 48 HOURS	AGAR 37° C. 24 HOURS
Patapsco River, Maryland	840	390	110
Rockburn Branch, Howard Co., Md.	620	430	96
Filtered Water, Balto. Co. W. & E. Co.	16	5	2
Shallow Wells, Baltimore County	602		70

Here also are given comparative counts upon gelatin and agar of the raw Thames River water as reported by Dr. A. C. Houston in the Ninth Research Report of The Metropolitan Water Board. The figures given are the averages for 42 tests, covering the period from October 9, 1911, to September 30, 1912:

SOURCE	GELATINE (20–22° C.) 3 DAYS	AGAR (37° C.) 20–24 HOURS
Raw Thames River Water	8088	347

Professor Chamot, in the April number of the *American Journal of Public Health*, voiced his objection to any such radical change in culture media, in part as follows:

"Out of some 1700 miscellaneous waters (not filtered) consisting of surface waters, well and spring waters, my records show that approximately 15 per cent had less than one colony per 2 c.c. on agar after forty-eight hours incubation at 37°–38° C. In a number of samples there were several thousand colonies on gelatin when the agar plates were sterile and in one case a polluted water (not with sewage) gave 60,000 colonies on gelatin at 20° C. but none on agar or other media at 37°.

"In other words, were the procedure recommended by the Committee on Standard Methods followed, the analyst in Central New York would be able to form no idea as to the true character of the water in at least 20 per cent of the cases; this means that fully one-fifth of his reports will be faulty and afford little future protection to his clients."

Probably the majority of water analysts who have been using gelatin medium and incubating at 18°–20° C. for 48 hours will agree with Professor Caird as to the inadvisability of substituting agar and growing at 37° C.

It will no doubt require a most convincing argument on the part of the advocates of the 37° C. count to show that such a change would not be a step backwards in our present day methods of water analysis.

Mr. John Gaub (by letter): The explanations in Mr. Caird's paper are valuable to the water analyst,

It appears to the writer that there are differences of opinion as to the choice of methods of procedure for the bacteriological examination of waters and that before beginning such an examination it should be definitely determined what is the true object of the investigation. Is it merely to decide whether colon and allied organisms are present, which may be pathogenic at the time of sampling, or should a reliable opinion as to the character of the water be presented, its present condition, what has happened in the past and what may happen in the future? In the first opinion the use of agar would be sufficient, but in the last the writer believes that the use of gelatin is necessary.

The use of gelatin should not be disregarded, for is it not the only thing we have at present at our disposal for a quick differen-

tiation between groups of organisms? With a little experience a worker can recognize the flora from different environments, and thus interpret his results with zeal.

In his article, in the *American Journal of Public Health* for April, Professor Chamot says: "Agar at 37 degrees fails to give the marked seasonal flora of a water supply and those important changes in this flora due to meteorological conditions. Neither is the analyst able to differentiate between a surface soil and deep soil flora. This information, however unimportant it may appear to some, contributes information for a better and sounder interpretation."

The counts on agar generally are a measure of certain soil organisms, and tend toward a seasonal distribution, which are to some extent affected by the meteorological conditions, for, with an excess of rain, drought or temperature, the counts on agar and gelatin are correspondingly affected. However, in a given period, the same number of plates will show a certain number of organisms or none, depending on conditions, in other words the agar counts follow a curve, and the gelatin counts follow a curve, however the agar do not indicate as much as the gelatin, especially when comparing them with the turbidity. In this comparison it will be seen that the gelatin keeps pace with the turbidity while the agar stays behind.

The writer agrees with Mr. Caird in the use of a properly cooled agar for mixing with the water samples, when making an agar plate, and in fact this statement may be made a little broader by including any kind of a plate, in any diagnosis. In many laboratories where the writer has visited, the agar was not *clear*, the worker claiming that this was an impossibility; this is, however, an erroneous idea, for with proper utensils and patience, one can prepare agar as clear as gelatin.

Messrs. Longley and Batton, several years ago, showed that at the Washington Plant the use of agar was an impossibility as a bacterial index. This opinion is today held at Pittsburg and Philadelphia.

Gelatin is very sensitive and in fact this is one of its disadvantages, but, when made properly, it has very delicate properties. And if incubated between 19.5 degrees C. and 21 degrees C. the results are much better than an agar at 37 degrees C.; not only this, but they are remarkably uniform, which is a very important factor in conducting a large purification plant. However, all this takes experienced help, elaborate equipment and expensive apparatus. Hence,

in a large plant the most sensitive medium is not too expensive, provided it is used correctly; for small variations in operation may cause large differences in cost compared to what the expense would be in small plants.

However important the use of agar may be or appear to some, it appears to the writer that the use of gelatin should not be given up; and that agar should not be depended upon solely, for there are times when one cannot use one without the other in order to supplement the work and enable the worker to interpret his results with zeal.

Mr. James M. Caird: It would be very desirable if some of the gentlemen who have sent discussions would follow them up with detailed results so that they could be tabulated in order to see how they compare with results from all sections of the country and in this way it would be possible to obtain more data and an intelligent decision could then be reached.

Mr. W. W. DeBerard: The following table of comparative gelatin and agar counts has been collected to show the indefiniteness of any ratio existing between gelatin and agar counts in some western waters:

RAW RIVER			SETTLED			EFF. S. S. FILTERS			PER CENT REMOVAL ON SETTLED	
Gel.	Agar	Ratio	Gel.	Agar	Ratio	Gel.	Agar	Ratio	Gel.	Agar
1600	56	28	630	15	42	140	10	14	77.8	33.3
1900	Spr		850	22	39	250	5	50	70.6	77.3
35000	800	44	700	20	35	115	4	29	83.6	80.0
2000	30	67	600	10	60	100	4	25	83.3	60.0
25000	200	125	800	15	53	210	Not det.		73.8	
2800	140	20	700	75	9	140	18	8	80.0	76.0
3500	45	78	1150	35	33	120	5	24	89.6	85.8
2400	50	48	700	18	39	130	7	16	81.4	61.2
66000	3000	22	550	17	32	85	7	12	84.6	58.8
800000	32000	25	850	40	21	100	5	20	88.3	87.5
Average		51			36			22	81.3	68.9

Infiltration Galleries

NO. 1			NO. 2			NO. 3		
Gel.	Agar	Ratio	Gel.	Agar	Ratio	Gel.	Agar	Ratio
1600	58	28	12	1	12	20	3	7
350	8	44	16	1	16	40	0	Inf.
200	18	11	350	27	13	17	2	8
175	4	23	45	3	15	15	0	Inf.
						40	2	20
						20	3	7
						50	2	25
						100	9	11
						70	12	6
Average		26			14			Infinity Av. of 7 = 12

APPLIED TO RAPID FILTERS			EFF. RAPID FILTERS			PER CENT REMOVAL	
Gel.	Agar	Ratio	Gel.	Agar	Ratio	Gel.	Agar
1560	55	28	40	3	13	97.5	94.5
1300	28	46	75	2	37	94.2	92.9
1500	Spr		30	1	30	98.0	
800	18	44	40	1	40	95.0	94.5
1600	55	29	20	1	20	98.8	98.2
3200	230	14	70	7	10	97.8	97.0
2200	100	22	60	5	12	97.3	95.0
600	26	23	60	0	Inf.	90.0	100.0
600	20	30	60	0	Inf.	90.0	100.0
750	38	20	65	0	Inf.	91.4	100.0
Average		28			Infinity Av. of 7 = 23	95.%	96.9

Raw			A storage reservoir—max. depth 65 ft.				
			Rapid Filter Eff'l't			Per Cent Removal	
Gelatine	Agar	Ratio	Gelatine	Agar	Ratio	Gelatine	Agar
3500	38	92	15	10	1.5	99.5	73.7
2000	50	40	90	10	9.0	95.5	80.0
900	36	25	18	4	4.5	98.0	88.9
700	20	35	10	3	3.3	98.6	85.0
1400	90	16	40	1	40.0	97.2	98.9
1600	130	12	12	3	4.0	99.3	97.7
2300	108	21	55	4	14.0	97.6	96.3
3000	24	125	5	2	2.5	99.8	91.7
2000	35	57	200	1	200.0	90.0	97.2
Average		47			31.0	97.3	89.9

Mr. D. D. Jackson: I move that it is the sense of this organization that both standards may be used.

The motion was seconded by Dr. Bartow and Mr. Diven.

Mr. D. D. Jackson: Is the American Water Works Association at the present time on record concerning bacteriological tests, and, if so, has it gone on record as approving the work of the Public Health Association? It really seems that this is a matter more peculiarly within the province of the American Public Health Association, and as the speaker understands, they are not all in accord with the present recommendation; and personally at least several members of the committee are ready to recommend that both standards be continued and they have really given us both in their report.

Mr. W. W. DeBerard: It would seem that this question might very well be left open to be threshed out by the new Section which it is understood is likely to be formed for taking up just this sort of thing. Let us leave this matter open for the new National Section of Bacteriologists and Chemists of the American Water Works Association, which it seems is big enough to stand alone. Conferences with other societies should be had as far as possible, in order to arrive at a national standard to which all results can be

referred. There are so many varying conditions, as Professor Caird and Doctor Bartow have found, that it is evident ratios are meaningless.

Mr. D. D. Jackson: The standard which is used in England is gelatin at 20 degrees. The standard used in Germany is the same. The French standard is gelatin for seven days, which to the speaker's mind is impractical. If we want to conform with the standards of other countries we should include gelatin as a standard. The speaker sees no reason why the organization should not express itself in regard to this matter. The speaker has been in communication with other members of the committee of the American Public Health Association and is quite well convinced that their standard will be changed to the double standard, probably at their next meeting.

Prof. J. M. Caird: The gelatin practically gives the total count, including that obtained by agar at 37½ degrees C. and if we are to have comparative results from all parts of the country we should use the gelatin media. Bacteria other than pathogenic forms will grow on agar at 37½ degrees C. and if this method is used alone it is impossible to learn the total bacterial content of any water, therefore gelatin should be used to determine the total number of bacteria. It should be noted on all reports what culture medium is used.

The pending motion by Dr. Jackson indorsing the use of both standards was put, and carried.

SOME NOTES ON THE USE OF ALUM IN CONNECTION WITH SLOW SAND FILTRATION AT WASHINGTON, D. C.

By William Firth Wells

1. ORIGINAL RECOMMENDATION

In the report leading to the adoption of slow sand filtration at Washington, Messrs. Rudolph Herring, George W. Fuller and Allen Hazen urged the occasional use of alum.

> In consideration of the full evidence, we recommend the construction of a complete system of slow or sand filters, with such auxiliary works as may be necessary for preliminary sedimentation, and the use of alum for part of the time. There is no reason to believe that the use of this coagulant will in any way affect the wholesomeness of the water.

2. POPULAR PREJUDICE

Popular prejudice was opposed to the application of alum, and for five years the plant labored, during periods of bad water, under a load which it proved impossible to completely reduce.

There were times when the cloudiness in the filtered water could be observed in a drinking tumbler, and the bacterial count sometimes rose above the liberal German limit of 100 per cubic centimeter. Often the filters were unfairly criticised even when giving a greater percentage purification than the average plant.

3. GENERAL PROBLEM

Few plants can continuously reduce a clay bearing water, such as the Potomac River, whose contamination fluctuates sharply and widely, to a water of assured constant purity. The efficiency of such a system must vary directly with the conditions, and it means at times an exceptionally high percentage purification. Experience has shown that slow sand filters alone can not deliver a satisfactory effluent when the turbidity of the raw water greatly exceeds thirty parts per million, however efficient they may be with a water

clearer than this. If combined with processes which can economically remove the bulk of the solids and keep the water on the beds below thirty parts per million they give remarkable results.

An ideal system is best prepared to handle that water at each stage of its purification. The slow sand filter is a most delicate instrument, best adapted for the final process.

4. AQUEDUCT SYSTEM

At Washington the water is treated in four steps:

1. Over one third of the mud which would otherwise enter the system is eliminated by closing the gates.

2. The coarser material (about half that which enters) settles out in two days' storage in Dalecarlia Reservoir.

3. Nearly two thirds, by weight, of the finer particles left sediment in two days in Georgetown and three days in McMillan Reservoirs.

4. Practically all the remainder is taken out by the filters.

On Chart No. 1 the turbidity readings have been arranged in order of magnitude. The area then under each curve represents the quantity of turbidity at that station, during the period, and the areas between the curves represent the quantity removed between two stations. These curves approximate closely the loga-

$$\log y = ax + \log b$$

rithmic form for values of y under 90. It is easy to integrate between $y=0$ and $y=90$ and obtain the area accurately enough for practical purposes. The constants for Chart No. 1 have been roughly determined and presented in the table.

CONSTANTS FOR CURVES ON CHART I

$\log y = ax + \log b$	1906–1911		1912	
	a	b	a	b
Great Falls	1.7	115		
Dalecarlia Outlet	1.0	120	1.5	100
McMillan Outlet	.54	135	.11	550

These curves illustrate two well-recognized characteristics of plain sedimentation:

1. settling progresses more rapidly at higher turbidities.

2. Even so, a week of storage is not enough to prepare the worst water for perfect slow sand filtration. In other words, the processes

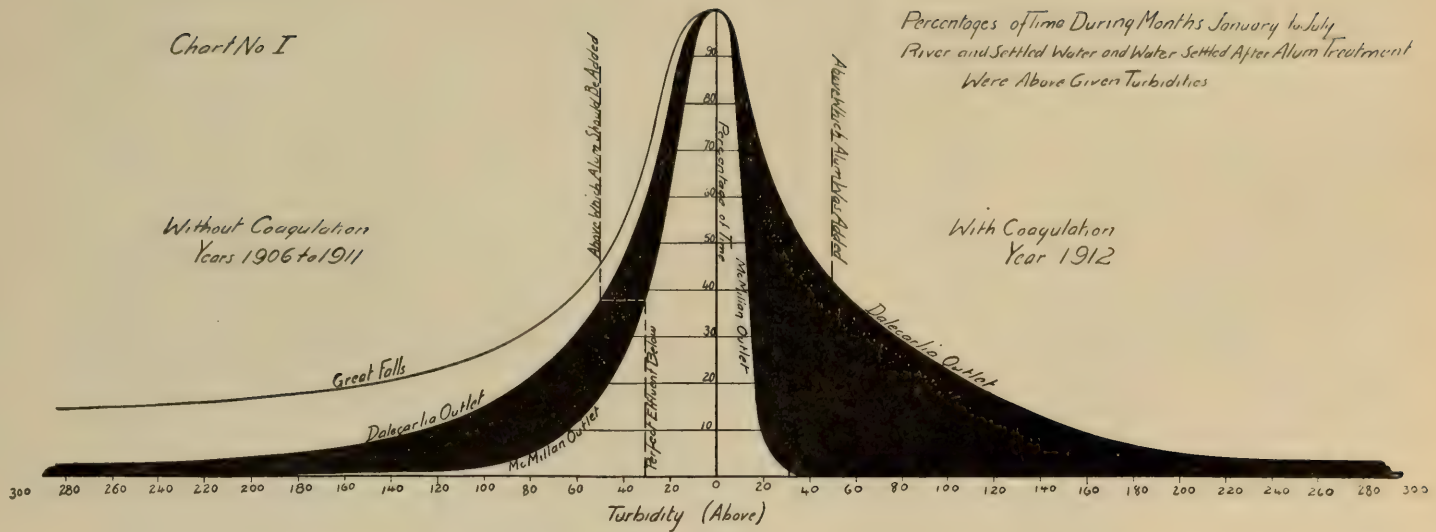


Chart No I
Percentages of Time During Months January to July
River and Settled Water and Water Settled After Alum Treatment
Were Above Given Turbidities
Without Coagulation
Years 1906 to 1911
With Coagulation
Year 1912
Above With Alum Should Be Applied
Above Without Alum Should Be Applied
Percentage of Time
Great Falls
Dalecarlia Outlet
McMillan Outlet
McMillan Outlet
Dalecarlia Outlet
Perfect Efficient Basin
90
80
70
60
50
40
30
20
10
300 280 260 240 220 200 180 160 140 120 100 80 60 40 20 0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300
Turbidity (Above)

possess a certain degree of flexibility tending to maintain a more constant condition in McMillan Reservoir, but are not flexible enough to render the filtered water constant. Whenever the turbidity of the water at Dalecarlia outlet is above 50, corresponding to a turbidity of about 75 in the river, the filters become overloaded.

5. PRELIMINARY TREATMENT

In 1908 Mr. Francis F. Longley reported an exhaustive series of experiments on the preliminary treatment of the water after two days' sedimentation in Dalecarlia Reservoir. He concludes, among other things, that:

> The desired improvement in the water can be effected by occasional coagulation, with subsequent thorough sedimentation in the two existing reservoirs. This process is so entirely *flexible* that with its use the final product of the filters, so much desired, is assured.

It is shown that the aqueduct system does not introduce enough flexibility for perfect filtration of the river water. Alum treatment admits of perfect flexibility for, by the proper addition of coagulant, the turbidity of McMillan Park Reservoir can under all conditions be kept below thirty parts per million.

6. USE OF ALUM

The opposition to the use of alum at Washington gradually subsided, with the increasing experience with mechanical filters throughout the country, until in 1910 Congress appropriated money for the construction of a coagulating plant and the purchase of alum. During the winter months, beginning 1911, alum was at times dumped directly into the conduit between Dalecarlia and Georgetown Reservoirs with excellent results. In 1912 the plant was in operation and alum was added to the conduit at Dalecarlia outlet when the turbidity there arose above 50, according to the schedule prescribed by Mr. Hazen and shown on Chart No. 2. This also shows how many days it was required to add given quantities of alum. The daily quantities are given by the lower black areas in Chart No. 3.

On March 23, Georgetown Reservoir was drained to begin the work of remodelling it for a sedimentation basin. The writer has chosen the months January to July for comparison in every case as it was during this period that most of the alum was added. Alum was added on eighty-three of the one hundred and eighty-two days, usually in amounts between 1 and 2 grains per gallon. The total

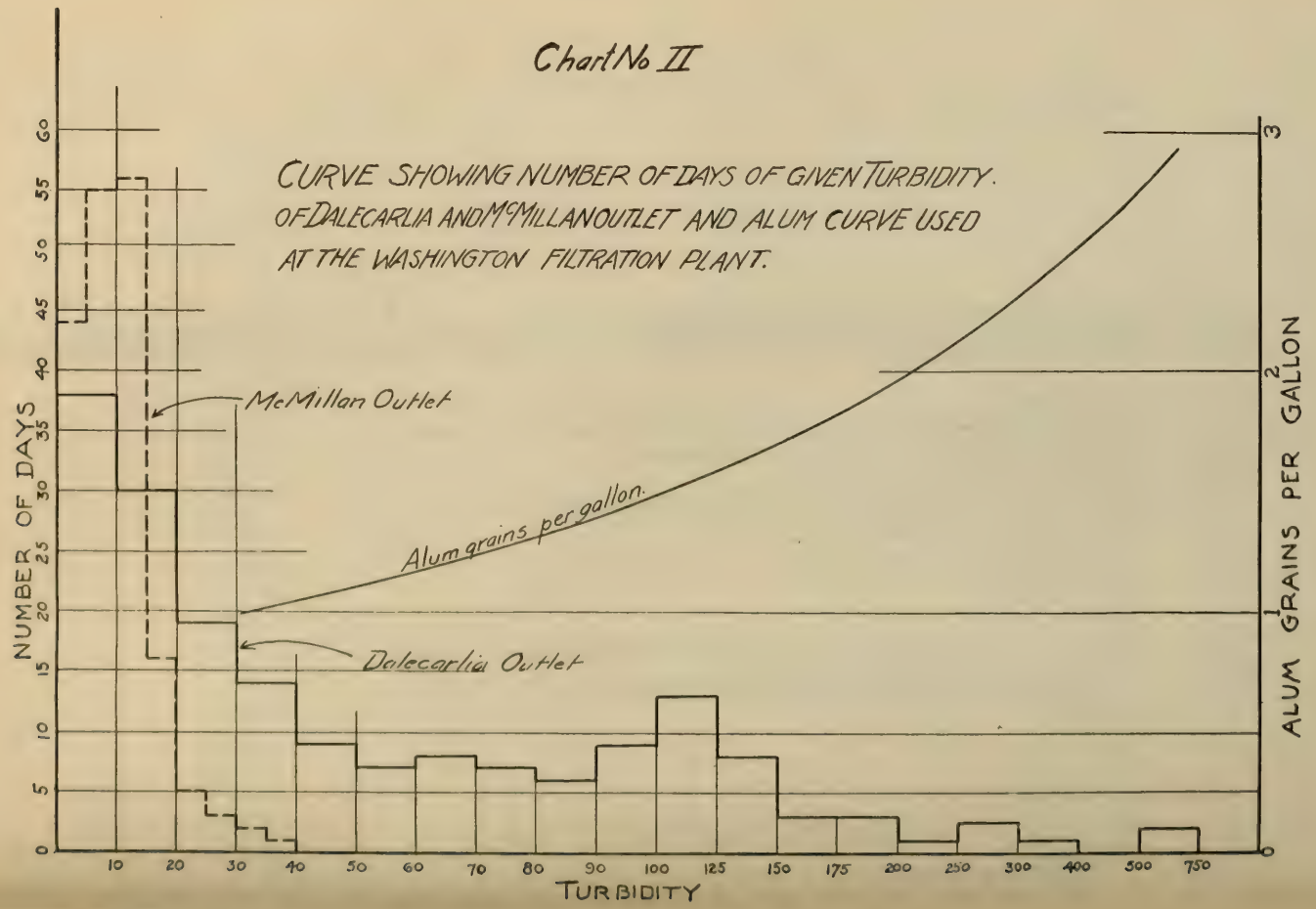


Chart No II
CURVE SHOWING NUMBER OF DAYS OF GIVEN TURBIDITY.
OF DALECARLIA AND McMILLAN OUTLET AND ALUM CURVE USED
AT THE WASHINGTON FILTRATION PLANT.
McMillan Outlet
Alum grains per gallon.
Dalecarlia Outlet
NUMBER OF DAYS
0
5
10
15
20
25
30
35
40
45
50
55
60
TURBIDITY
10
20
30
40
50
60
70
80
90
100
125
150
175
200
250
300
400
500
750
ALUM GRAINS PER GALLON
0
1
2
3

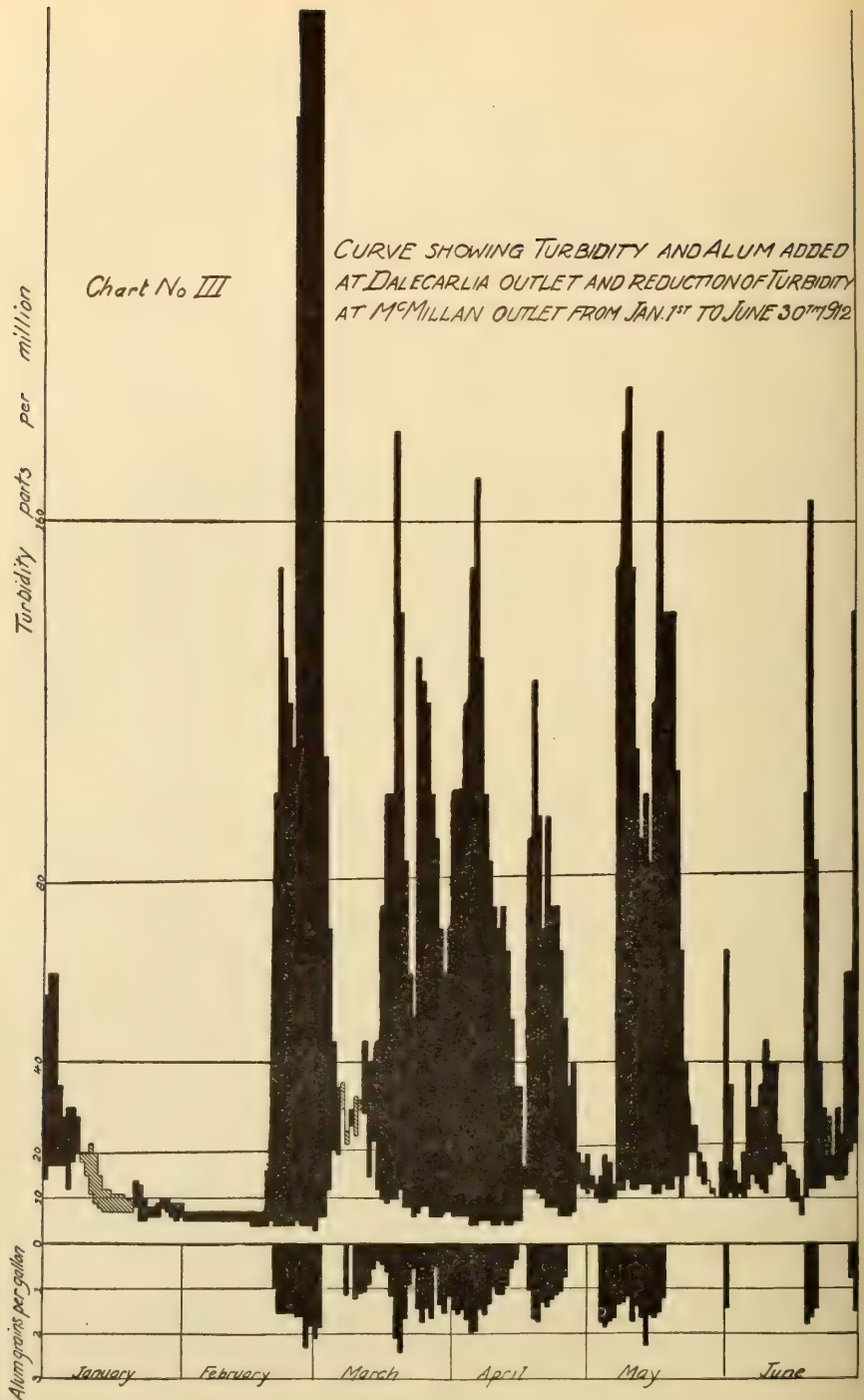


Chart No III
CURVE SHOWING TURBIDITY AND ALUM ADDED AT DALECARLIA OUTLET AND REDUCTION OF TURBIDITY AT McMILLAN OUTLET FROM JAN. 1ST TO JUNE 30TH 1912
Turbidity parts per million
100
60
40
20
10
0
Alum grains per gallon
3
2
1
January
February
March
April
May
June

amount was 863,230 pounds, and the water pumped during the period was 11,634,000,000 gallons. The average cost per 1,000,000 gallons during the six months figures out to nearly $.70.

7. EFFECT ON MCMILLAN PARK RESERVOIR

The results of the treatment as may be observed by comparison with the same period during the previous five years (on Chart No. 1) exceeded the most sanguine expectations. The slight rise in the curve of McMillan outlet is due to unavoidable difficulties met with, at first, in the long spells of bad weather. Except for this McMillan Reservoir was kept uniformly in much better condition than was requisite to deliver a perfectly clear effluent from the filters. Chart No. 3 shows in detail the effect of the alum. The schedule is liberal and with a little trimming would still admit of a clear effluent. But the excellent condition of McMillan outlet insured a higher bacteria removal than could be obtainable when the alum was just sufficient for a clear effluent, and surely the slight added expense is amply justified in securing a water as pure as from a spring at the nation's capital.

8. FILTERED WATER

When the turbidity of the water going onto the Washington filters is under 20 for 90 per cent of the time, and under 10 for 30 per cent of the time, it is hardly necessary to discuss the filtered water in detail. The results are given by months in the following table and averaged in Chart No. 4. There are factors, however, which go to make the water even better than under similar conditions without the use of alum. First, the turbidity is much coarser than would be the same turbidity left after plain sedimentation. Not only is it easier for the filters to take it out but it puts them in better condition. Second, by keeping the water on the beds in uniformly clean condition the filters become purged of the resistant organisms lodging within its body. These are mostly hardy soil forms and spores which can survive the long stumbling passage through the filters, which may take days or weeks. This leads to a remarkably high purity of the filtered water. For these reasons, also, it is not advisable to add hypochlorite to the filtered water, viz: 1. In reasonable quantities it will not kill these forms. 2. They are entirely harmless. 3. The water is of the highest purity without it. These changes in the characteristics of the raw water, also, would make it more adaptable to higher rates of filtration, whereby the growths in the underdrains would have a less relative importance

Turbidity 1912

	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST
Great Falls	22	580	615	222	165	207	970	59
Dalecarlia Inlet	22	250	207	110	155	66	496	
Dalecarlia Outlet	18	82	96	78	72	43	186	43
McMillan Outlet	12	5	14	7	12	13	22	24
Filtered Water	1+	0	0	0	0	0	0	0

Bacteria 1912

	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST
Dalecarlia Inlet	7,900	36,650	18,250	4,010	8,570	860	1,590	534
Dalecarlia Outlet	7,130	30,350	13,250	2,980	2,100	394	780	221
McMillan Outlet	3,640	4,410	2,100	180	179	103	60	91
Filtered Water	203	89	53	8	5	3	4	3

9. FILTER OPERATION

A possibility was at first feared that some alum floc would carry over and clog the filters, rapidly increase the loss of head and shorten the runs. No floc ever appeared in McMillan outlet, nor until March twenty-third when Georgetown Reservoir went out of service, was any observed in McMillan inlet. On the contrary, the load being taken from the filters, the runs were lengthened and the cost of cleaning the filters was reduced. It is hard to get an accurate measure of the exact saving in filter operation, due to alum treatment, as the work on the filters is more or less arbitrary. But some idea can be gained from the quantities of sand handled. During January to July 1906 to 1911, the average per month was 1808 cubic yards; the same months 1911 it averaged 1353 cubic yards, and in the exceptionally bad months of 1912 it was only 1259 cubic yards. This is a reduction of 549 cubic yards or 30 per cent of the original quantity and nearly a half of the present amount. Figured at the average cost per yard of $.34, the saving during the six months was $1180 or 14.5 per cent of the cost of alum during the period.

10. RATE

The possibility of reducing the cost by increasing the rate has not been investigated under the favorable conditions created by

the preliminary treatment. Judging from the rate experiment carried on, previous to coagulation, it would seem feasible to double the rate or even raise it much higher and still maintain a high standard of purity. The problem of finding the minimum of the equation:

$$\text{cost} = F\ (\text{rate, alum})$$

for a given condition of filtered water presents an attractive promise.

11. CONCLUSIONS

1. Seven days' storage is not sufficient to prepare the Potomac water, when the turbidity is above 100, for satisfactory slow sand filtration.

2. Preliminary treatment with alum introduces an ideal flexibility into the system, whereby the turbidity of water flowing onto the filters may be kept uniformly below 20 (or lower if desired).

3. Filtration of this water yields a water of constant purity, perfectly clear, and with less than 10 bacteria per cubic centimeter.

4. The few bacteria surviving filtration are mostly harmless hardy soil forms, making it inadvisable to add hypochlorite.

5. Cutting down the peak load greatly reduces the cost of the filter operation, and the treated water keeps the beds in better condition.

6. The rate of filtration following alum treatment can be more than doubled to advantage, and an economical balance struck between the rate of filtration and the quantity of alum.

Days Water Was of Given Turbidity—January to July

Turbidity	Number of Days							Percentage of Days				
	1906–1911			1912				1906–1911			1912	
	G. F.*	D. O.†	M. O.‡	G. F.*	D. I.§	D. O.†	M. O.‡	G. F.*	D. O.†	M. O.‡	D. O.†	M. O.‡
0–10	33	49	22 / 162 } 184	29	33	38	44 / 55 } 99	3.60	5.42	2.40 / 17.62 } 20.02	20.80	24.33 / 30.35 } 54.68
10–20	190	222	88 / 140 } 228	28	29	30	56 / 16 } 72	20.75	24.60	9.60 / 15.30 } 24.90	16.42	30.95 / 8.85 } 39.80
20–30	154	171	105 / 83 } 188	20	14	19	5 / 3 } 8	16.78	18.80	11.45 / 9.05 } 20.50	10.83	2.74 / 1.68 } 4.42
30–40	85	75	60 / 52 } 112	11	12	14	2 / 1 } 3	9.30	8.35	6.56 / 5.70 } 12.26	7.66	1.10 / 1.10
40–50	77	57	37 / 34 } 71	5	13	9		8.38	6.90	4.05 / 3.76 } 7.81	4.94	
50–60	44	69	46	4	8	7		4.82	7.40	5.00	3.82	
60–70	35	52	33	5	7	8		3.83	5.75	3.60	4.31	
70–80	24	44	28	6	3	7		2.68	4.46	3.06	3.82	
80–90	28	28	11	5	4	6		3.00	3.10	1.20	3.30	
90–100	25	31	4	3	3	9		2.70	3.42	.44	4.95	
100–125	37	29	2	4	13	13		4.00	3.20	.22	7.05	
125–150	17	29	7	8	8	8		1.88	3.20	.77	4.40	
150–175	11	7	1	1	3	4		1.21	.77	.11	2.20	
175–200	18	17	1	9	5	4		1.90	1.88	.11	2.20	
200–250	16	10		6	5	1		1.77	1.10		.55	
250–300	16	6		5	1	2		1.75	.66		1.10	
300–400	31	7		6	7	1		3.37	.77		.55	
400–500	15	2		5	3			1.66	.22			
500–750	20			4	3	2		2.21			1.10	
750–1000	8			5	4			.88				
1000–1500	15			2	4			1.66				
1500–2000	7			1				.77				
2000–3000	10			10				1.10				
Total...	905	905	905	182	182	182	182	100	100	100	100	100

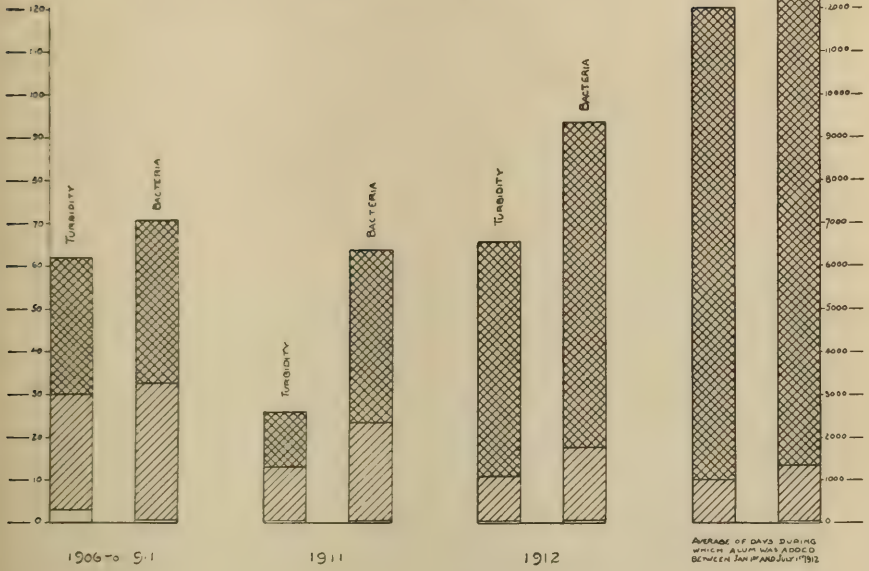
* Great Falls. † Dalecarlia Outlet. ‡ McMillan Outlet. § Dalecarlia Inlet.

Bacteria and Turbidity Averages—January to July

	1906–1911		1911		1912		Days alum was added	
	Turbidity	Bacteria	Turbidity	Bacteria	Turbidity	Bacteria	Turbidity	Bacteria
Great Falls	128		70		302		678	
Dalecarlia Inlet		9,000	39	8,735	135	12,707	302	22,534
Dalecarlia Outlet	62	7,043	26	6,387	65	9,367	120	15,335
McMillan Outlet	30	3,242	14	2,357	11	1,769	10	1,310
Filtered Water	3	73	0+	46	0+	60	0	28

Chart No IIII

TURBIDITY AND BACTERIA AVERAGES FOR MONTHS FROM JAN TO JULY FOR DALECARLIA OUTLET McMILLAN OUTLET AND FILTERED WATER RESERVOIR.



1906 to 9.1 1911 1912

DISCUSSION

Mr. J. M. Diven: When the question of filtration for the City of Washington was under consideration, the use of coagulant was practically on trial. At the hearing before the United States Senate, citizens of Washington brought all possible pressure to bear on the committee, to prevent the adoption of a rapid filter, or any filtration requiring the use of a coagulant. Those present "defending" or advocating rapid filter did not say anything in opposition or derogatory to slow sand filtration, but merely sought to show the efficiency of mechanical filters and their comparatively low cost of installation.

But all this was some years ago, and this change of sentiment goes to show how the prejudice against the use of "chemicals" has disappeared; probably due to the fact that people have learned that "rapid filters" are not chemical filters, and that the action of the chemicals used is merely mechanical.

Waters varying in character sometimes vary suddenly, as is the case with the Potomac river, and many, or most other surface waters, can, in the speaker's opinion, be best treated by the more elastic mechanical or rapid filters.

Mr. D. D. Jackson: It is gratifying to note that the so-called chemical treatment of water is coming into its own. It has been a hard fight, and those people who started the fight were in a losing game for quite a number of years while the chief opposition was the medical profession. It seems that at least in this country the prejudice has been entirely removed against the chemical treatment of water, not only with alum but with other chemicals as in sterilization. This same prejudice at present exists in England, and to a large extent in Germany and France; but the speaker believes that mechanical filtration will be the method that will be most extensively used in the future both in this country and abroad.

Mr. W. F. Wilcox: Referring to that "trial" that they had of mechanical filters at Washington, the speaker noticed that it was stated in that proceeding that the typhoid fever rate at Atlanta, Georgia, and Macon, Georgia, both increased after the installation of mechanical filters. At Atlanta and Macon, Ga., their original supply came from a small spring and branches; and the installation of the filters was coincident with their changing the supply to a

river supply in both cases. There was some increase of the typhoid fever rate due to the fact that they were just starting their filters.

Mr. M. N. Baker: It is to be hoped that Mr. Longley or Mr. Hazen will state the facts as they see them in regard to the developments at Washington. The second paragraph of this paper which is a quotation from the original report of Messrs. Hering, Fuller and Hazen on filtration at Washington, contains a recommendation for the use of alum when needed. The final adoption of a coagulant there is the outcome of a long fight against the use of alum. It is not a condemnation of slow sand filtration, nor does it prove that mechanical filtration might better have been used in the first place. As you all know there is and has long been a strong prejudice against the use of alum. That prejudice still exists, and it is used for all it is worth when the rival systems of filtration are up for discussion. The prejudice is weakening, perhaps, but in the public mind it still exists and must be met. Among filtration experts there has unquestionably been a strong drift toward mechanical filtration, but that has had little or nothing to do with the course of events at Washington.

Mr. James M. Caird: There are very few places where the English system of filtration will give better results than the American or coagulation system and the first cost of the American system is much less than the English. Most of the English systems are using coagulants and sterilizing solutions at least part of the time, which places them on about the same footing as the American system, but still the first cost item is much larger.

There is still, in some places, a great deal of prejudice against the use of any coagulants. This prejudice is caused by a few medical men who think they know everything about water purification and the minute you talk about the use of a coagulant or sulphate of alumina they say, "That is alum. You cannot take it out." You can talk chemistry to them until you are black in the face and you will not succeed in convincing them. The prejudice, in most cases, is due to the ignorance of these physicians, who, if they ever knew anything about chemistry, forgot it a long time ago. They say, "Well, you put alum in, and you cannot take it out, and that is all there is to it, you are giving the people alum and it is awfully bad for them." After they have done the damage they go off and

sit down, but the damage is done. They have great influence with the general public.

President Gwinn: At the time the filtration of the Potomac was being considered by the Senate Committee your President had charge of a mechanical filtration plant which had been in operation about eight years, and the speaker was one of those who were invited to go to Washington and tell what he knew about it. This unfounded prejudice against alum still exists, and as Mr. Baker says, we have to reckon with it. In Terre Haute, as elsewhere, the effect of turning on and off the water is to introduce air into the mains, which has the effect of making the water look white, and when people see it they say it is the alum. The people say, "You put in alum and you can't take it out." That argument is used very many times. We are still using alum and think the prejudice is weakening to a certain extent, but nevertheless it still exists. One of our customers told the speaker a short time ago that we were becoming a city of constipated people, all due to the use of alum. Now you might talk to a man like that until, as Professor Caird says, you are black in the face, but you could not change his conviction that because you put alum in the water it must be there.

Mr. James M. Caird: A few years ago when a plant was placed in operation, the General Manager of the Water Company stated that we would have to find some other method than sulphate of alumina to coagulate the water. This plant had been in operation about three days, the average amount of coagulant used was about $\frac{3}{4}$ grain per gallon. The General Manager stated that a chemist had found alumina in the water, the amount being 60 grains per gallon. On investigation it was found that this "chemist" had made up a solution of potassium hydrate, using the tap water, and of course he precipitated all of the calcium and other salts, and because it was white, he made the statement that it was alumina.

Mr. Charles N. Kinney: Has any one present used sulphate of iron in water purification? Has any one had experience with the use of that material?

Mr. George G. Earl: There seems to be a prejudice against the use of alum in almost every part of the country, and this prej-

udice exists in New Orleans. The assurance that no sulphate of alumina is used in the New Orleans plant, but that sulphate of iron and lime are used exclusively, seems to satisfy everybody.

Mr. John M. Diven: Mr. Earl states that the use of sulphate of iron and lime is satisfactory to everybody. Does that include himself?

Mr. G. G. Earl: Yes, because the results with New Orleans water are better and cheaper with the lime and iron treatment. If the contrary were true, the prejudice against the use of sulphate of alumina, in which the speaker does not share, would have to be overcome as best it could.

President Gwinn: At one of the Indiana state conventions an incident was related with reference to a certain city where they were contemplating the use of hypochlorite, and this intention had been announced in advance. About a week before the first shipment of hypochlorite came, the water works department received a complaint from one lady to the effect that the hypochlorite they were using was bleaching her hair.

Mr. F. F. Longley: Mr. Wells' paper describes admirably a consummation that has long been the aim of those who have worked for the perfection of the Washington water supply. The word "perfection" is used advisedly because it must be clearly understood that during the six years that the sand filters were in operation with no preliminary treatment except sedimentation, they gave results that were admirable, the average bacterial counts in the filtered water for months at a time being from 10 to 20 per c.c., and the turbidity practically zero, thus proving the entire suitability of the filters for normal conditions of operation.

The tone of some parts of the discussion of this paper has been in the main one of jubilation. The "I told you so" tendency on the part of the ardent advocates of mechanical filtration has been obviously strong. Several of the speakers have made mention of certain hearings before the Senate Committee on the District of Columbia in Washington prior to or during the construction of the Washington filters. It would be unfortunate to let a mistaken impression stand as to the exact issue at these Washington hearings.

It is true that there was a strong prejudice on the part of the

Medical Fraternity in Washington against the application of alum or any other chemical to the water. The engineers who were advising in the matter, however, gave approval almost equally favorable for both mechanical and sand filters, which is shown by the following extracts from some of the reports given at that time.

Senator McMillan reported that

> "The result of this discussion (relating to sand and mechanical filters) established the fact that the slow sand filter, wherever it had been put into operation, had produced uniformly good results, both in clearing the water of turbidity, and also in removing bacteria."
>
> "The experts were of the opinion that the mechanical system, when properly operated, was capable of producing superior results as to the clearness of the water, and equally good results with the sand filter as to bacterial efficiency. It was admitted that such results had not been uniformly attained and this was held to be due to a variety of causes which had prevented the mechanical systems from being managed with a view to obtaining the highest efficiency of which they are capable."

The following paragraphs are from the report of Messrs. Hering, Fuller and Hazen, dated February 18, 1901:

> "As to the relative merits of the two systems of purification studied by Colonel Miller, namely, the treatment of plain subsided waters by sand and by mechanical filters, his conclusion is correct, namely, that the latter system would be the more efficient, and the more judicious one for the city of Washington to adopt.
>
> "Since his investigations were instituted, some improvements have been made in the general processes of both slow and rapid filtration. Relative to the former, this progress applies, for very turbid claybearing waters, to the use of coagulants when needed."

> "Within the past few months material improvements in mechanical filters have been developed in connection with several municipal water supplies."

> "The question of deciding between the two systems of purification, with the improvements above indicated, is in some respects a difficult one. In character the water for Washington is intermediate between the water for Pittsburgh, where sand filters are best adapted to the conditions, and the water for Cincinnati, where American filters are preferable. If the Potomac water were more turbid, or turbid for longer periods than the records show, mechanical filters would unquestionably have the preference. If it were less turbid, or if turbid periods were of shorter duration, the advantage would clearly lie with sand filters.
>
> "Practical experience with sand filters is much more extensive and more favorable than that with mechanical filters. Our knowledge of what they will do rests not alone upon experimental investigations, but upon actual use for many years by some of the largest cities of the world. The force of this

statement is somewhat reduced, however, by the fact that the raw water at Washington is more turbid than the raw water at the places where sand filters have been generally used.

"Our knowledge as to the results that can be obtained by mechanical filters rests more upon experimental evidence than upon results obtained in practice. Nevertheless, these investigations have been made upon such a scale and with such care as to give the greatest confidence in their results."

"After a full consideration of the various aspects of the problem we are of the opinion that the long and favorable experience with sand filters, particularly in the light of the effect which they have had upon the health of the communities using them, should be given greater weight than the present evidence that American filters are able to give substantially equal hygienic efficiency. In view of the fact that there is no available evidence of decided advantage to be gained by adopting the newer method, we prefer in this case to adhere to the one supported by long precedent."

The report of these engineers concluded with the recommendation which Mr. Wells quoted in the first paragraph of his paper, namely, a recommendation in favor of sand filters, with provision for preliminary chemical treatment during only part of the time.

This Board of Engineers saw clearly and accurately the one defect that was likely to develop in the operation of sand filters without preliminary treatment. They freely admitted the adequacy of mechanical filter treatment if properly carried out. The conditions were such that either system would be applicable, and the choice would be difficult. The ideal arrangement seemed to be a combination of the advantageous features of both systems, and their recommendation was made to cover this.

The prejudice against chemical treatment which was voiced by the Medical Society, and which was undeniably strong, was sufficient, however, to postpone the adoption of preliminary chemical treatment until the said Medical Society should become more convinced than they were at that time that the advantages of chemical treatment were more than enough to offset the more or less hypothetical disadvantages. The official attitude was indicated by certain discussions before the Senate Committee on January 28, 1903, in the course of which one of the keenest opponents of the chemical treatment brought up the point "whether or not the question of preliminary treatment could not be deferred until it is actually and eminently called for." Consideration was given at that time to the question "could not these supplementary works be installed without material increase in expense of installation at any time in the future?" Which question was answered in the affirmative.

At the time the final consideration was given to this matter, it was plain that there was practically no difference in the cost of the two systems. While the cost of constructing sand filters was larger than for mechanical filters, the maintenance cost was less and, everything considered, there was no certain advantage for either on this point.

In the light of more than a decade of experience since that time, a period during which rapid developments have been made along both the lines then considered, the same statement holds true in a general way. It cannot be fairly said, therefore, that the District of Columbia would, in the long run, have saved much, if anything, by adopting mechanical filters in the first place.

It will be seen, therefore, that the various steps taken in this matter ten years or more ago, were entirely logical, and that no evidence which can be brought forward now can make this appear in any other light. Since the carrying out of that part of the original recommendation which related to preliminary chemical treatment had been deferred, it was also logical, when the minor defects resulting from this omission became apparent, that they should be studied and used in every legitimate way to overcome the prejudice. This was done, and the efforts were crowned with success when in 1910, Congress, with the approval of the Medical Society of Washington, provided for the carrying out of the original recommendation for preliminary chemical treatment.

There is nothing in the history of this development which suggests error in the judgment of the early workers and advisers on this project, or condemnation of sand filtration. Neither does it indicate that there would have been any advantage gained if mechanical filters had been adopted at the beginning.

The system, as it now stands, gives results which cannot be criticised from any point of view. With the several days of storage and sedimentation which the reservoir system of the Washington aqueduct provides, and with occasional coagulation to help the natural improvement of the water at those infrequent times when sedimentation alone is not sufficient, and with the filters which have proven themselves the very perfection of efficiency for the average conditions of the applied water, the system is so perfect and gives such satisfactory results that there should be no room for vain regrets over all the obstacles that have had to be overcome to attain this end.

MODERN FILTER PRACTICE

By Nicholas S. Hill, Jr.

The Little Falls plant of the East Jersey Water Company was put in operation on September 4, 1902. The opening of this plant marked the beginning of what we may term "modern mechanical filtration." There were several mechanical filtration plants in use prior to that time, but they were all more or less inefficient and did not, with possibly two or three exceptions, properly represent the art of mechanical filtration as it is practiced today. Experiments had been carried on at Louisville, Kentucky, from 1897 to 1899, on the water of the Ohio River and plans had been prepared for a mechanical filtration plant at that city, but it was not until several years later (1909) that the Louisville plant was actually put in operation and, therefore, the Little Falls plant may be said to mark the beginning of up-to-date mechanical filtration. It, therefore, seemed appropriate to the author to present, after the passing of the first decade, a paper dealing with filtration as it is at present practiced, and to attempt to point out by comparison a few of the advances that have been made in the intervening time.

The data included in this paper were compiled with the aid of the superintendents of the plants listed, many of whom are members of this association. This information has been augmented by data taken from the files of the engineering press.

That the process of filtration has grown by leaps and bounds during this period is shown from the fact that in 1903 only about sixty cities and towns were served with filtered water, while it is estimated that there are at the present time approximately four hundred cities and towns in this country with a total population of about 12,000,000 using filtered water. This represents an increase of about 350 per cent in the number of people supplied with filtered water. The tables which are presented in this article do not begin, of course, to cover the total number of cities, but are simply taken as representative plants and vary in capacity from 750,000 gallons per day to 400,000,000 gallons per day.

Filtration as it is understood today may be classified into four types:

1. Slow sand filtration.
2. Modified sand filtration.
3. Mechanical filtration.
4. Double sand filtration.

It will not be necessary to define or describe more than briefly each type of filtration plant as all of you are doubtless familiar with the processes employed in each type and are familiar with the limitations which govern the selection of any type as being best adapted for any particular water.

It has been found as a result of very careful and extended experimentation at Lawrence, Louisville, Cincinnati, Pittsburgh, Montreal, New York and other places that the design of a filtration plant must depend upon several variable factors, and that the proper style of filtering units, their capacity, the rates of filtration best adapted, the thickness of the sand and gravel layers, the size of sand grains, the period of sedimentation or coagulation, in short each detail must be worked out for the plant in question. This can be properly done only after a close study of the quality of the water and of all the local conditions for a period covering at least several months.

Within the last five years it has become the practice to increase the efficiency of filtration plants and maintain this efficiency at a very high figure by the use of a sterilizing process applied either before or after the water is filtered. The use of a sterilization process has also permitted the employment of higher rates of filtration since it has become necessary primarily to remove only the suspended matter and a portion of the dissolved matter without the necessity of obtaining such a high efficiency as formerly in reducing the number of bacteria, as these are reduced by the sterilization process.

1. SLOW SAND FILTRATION

A slow sand, or simply a sand filtration plant as it is sometimes referred to, consists primarily of a bed of moderately fine sand through which the water filters at a low fixed rate. When the water to be filtered contains appreciable amounts of sediment, a sedimentation basin is introduced. This relieves the filter of a large burden and consequently increases the length of time between filter cleaning, at the same time decreasing the cost of operation. The

number and size of the sedimentation basins depend naturally on the size of the plant and the amount and density of the suspended matter. The shape of the basin depends largely on the topographical conditions at the location of the plant. At plants having but one basin, cleaning is usually facilitated by dividing the basin into two halves and cleaning one side at a time.

Table 1 on page 387 shows the size, capacity and period of retention of the sedimentation basins in those plants that use sedimentation as an aid to filtration. It will be observed that in this and the following tables the plants are listed in the order of their construction and the last plant given is the one most recently constructed. Only four of the eleven slow sand filtration plants shown in the tables use sedimentation. The average area of the basins is 16.2 acres with an average depth of 12 feet. The maximum sedimentation capacity is 6.57 times its daily consumption, while the average sedimentation capacity is 2.2 times the average daily consumption of the plants using sedimentation. The maximum period of sedimentation is 158 hours at Washington, D. C., where water from the Potomac River is used. The average period is 79.2 hours. The very short period of sedimentation at Dover, New Hampshire, is explained by the fact that the turbidity is nearly all in the form of iron salts which are precipitated upon oxidation and settle very rapidly.

The compiled data concerning the filter beds are given in Table 2. This table shows the number of beds, the size of each, its capacity per day, the rate of filtration per acre employed, and the average length of run, together with the thickness of the sand and gravel layers and the effective size and uniformity coefficient of the sand.

The size and shape of the filter bed is subject to wide variation. The large sized bed is somewhat cheaper to build in proportion to its size than the small bed. On the other hand, it is advisable to have a sufficient number of beds to allow one to be put out of service for cleaning without increasing the rate of filtration in the others beyond the safe limit. This, of course, applies particularly to plants of small capacity. In plants of more than 30,000,000 gallons capacity the area of each bed can easily be as high as one acre and be conveniently operated.

The smallest beds are those at Putnam, Connecticut. At this plant there are three beds each 69 x 51 feet and having an area of 0.075 acre. At Washington and Providence the beds are approximately 250 x 175 feet and have an area of 1 acre. The average

size for the entire eleven plants is 194 x 123 feet which equals an area of 0.6 acre. The capacity of each bed per twenty-four hours depends upon the rate of filtration per acre. The rate per acre has been steadily raised. At first, rates of 2,000,000 gallons per acre per day were used. It was found by experimentation that this rate might be safely increased and the rate was set at 4,000,000. More recently rates of 5 and 6,000,000 gallons per acre per day have been successfully used. This increase in rate is not conspicuous in the table, as the rates in the older plants have been raised from time to time to meet increases in water consumption. The maximum rate of filtration is used at Dover, New Hampshire. This, however, is hardly a fair example, as the quality of the water to be filtered is excellent except for the large amount of iron present. This is removed by a coarse filter capable of being operated at very high rates. Toronto is perhaps the best example of recent construction. Here the beds have an area of 0.8 acre and are operated at a rate of 6,000,000 gallons per acre per day. The average rate for the eleven plants is 4,100,000 gallons per acre. There is considerable variation in the depth of the sand layers. The greatest thickness of sand is 54 inches at Lawrence, and the minimum thickness is in the beds at Pittsburgh, where only 24 inches of sand are used. The thickness of the gravel layer is practically constant and is usually 12 inches. The effective size and uniformity coefficient of the sand is also very regular. The average effective size is 0.28 millimeters and the uniformity coefficient is 2.4. The sand used in sand filtration has a greater uniformity coefficient than that used in mechanical filtration. The sand used in sand filter plants is usually obtained from some adjacent bank and is only graded by washing and coarse screening. The sand used in mechanical plants is more often a graded sand sized particularly for water filtration.

The method of drainage of slow sand filters has not been changed, but still consists of plain half round tile laterals covering grooves in the floor of the filter. In different plants the arrangement of these laterals is different. In some there is a main collector running the length of the bed with the laterals placed at right angles. In other plants the laterals run lengthwise of the bed, meeting like the branches of a tree in one common point, and increasing in size as they approach this collecting well. At the Montreal municipal plant, which is one of the most recent sand filtration plants built in this country, the system of underdrains consists of 8 inch half

round laterals covering grooves in the filter floor, and a main collector 2 feet 6 inches wide, cast in the concrete floor. The collector extends the long way of the bed, down the center line, and the laterals are laid at right angles to it and on either side at intervals of $9\frac{1}{2}$ feet.

The quality of the raw water, the period of sedimentation and the average length of run of the filter, in each plant, have been grouped together in Table 4. It so happens that in the list of plants taken, only four of the eleven require a sedimentation basin in advance of the filters. The necessity for sedimentation in these four is evident from a comparison of the turbidities in the various plants. At Washington, for example, the average turbidity is 106, and at Pittsburgh the average turbidity is 40, whereas, at Reading, which has the highest turbidity of any of the plants not using sedimentation, the average is but 18. As before remarked, the sedimentation basin at Dover, New Hampshire, is used for the removal of iron, and not because of turbidity in the water. As a general proposition, the run of a filter depends upon the amount of sediment in the raw water. There are, however, several other factors which affect the length of the run, such as, the character of the suspended matter, the effective size of the sand, rate of filtration and the head under which the beds are operated. No comparison can be drawn between the turbidities and the length of run from the plants under consideration, as the several factors are too variable. The average length of run of each for the eleven plants is 35.7 days. The maximum length of run is obtained at Washington. At this plant the average length of run is 68 days. This long period between washings is obtained by the use of a long period of sedimentation prior to filtration. The shortest period between washings at any plant is 20 days. This occurs at the Pittsburgh plant. Here the period of sedimentation is only 14.4 hours, while the turbidity is one-third that of the turbidity at the Washington plant. Unfortunately, we have no data concerning the turbidity of the water after sedimentation, and, therefore, do not know the exact amount of turbidity which is carried on to the filters themselves.

The removal of suspended matter by sedimentation for a given sized basin will depend upon the character and density of the suspended matter. If the suspended matter is in the form of very finely divided silt, the percentage removed by the sedimentation basin will be very much smaller than if the suspended matter is very coarse and of a higher specific gravity.

It may also be noted in passing, that only two of the sand filtration plants use a sterilization process as an adjunct to filtration.

2. MODIFIED SAND FILTRATION

Modified sand filtration is used in a few instances where the turbidity, and more particularly the color, is so high that they cannot be properly removed by simple sand filtration, or where it is impossible to allow space for basins large enough to provide for plain sedimentation.

Four plants are described in Tables 1, 2, 4, 5 and 7.

The average size and storage capacity of the sedimentation basins are much smaller than for the slow sand plants. The maximum sedimentation capacity is only 2.66 times the daily plant capacity as compared with 6.57 for the slow sand filtration plants. The average sedimentation period is 29.1 hours against 79.2 hours for slow sand filtration plants.

An examination of Table 2 shows that the filters in the plants of this character are very similar in size, capacity, rate of filtration and all other details to the sand filters where pre-coagulation is not used.

Table 4 indicates that although the average amounts of color and turbidity in the raw water at plants of the modified type are much higher than in the slow sand filter plants, the average length of run of filter beds is the same. It will be noted too that the average period of coagulation and sedimentation is 29 hours while the maximum is 64 hours. The Lancaster plant only allows a coagulation period of 4 hours and 20 minutes. This short period is permissible because of the character of the raw water which contains much iron in suspension. The sedimentation of the coagulated matter is, therefore, more rapid than would normally be the case. Alum is used as a coagulant at all plants, and at Poughkeepsie calcium hypochlorite is also applied.

The question of whether sand filter beds should be covered or remain open is naturally one of geography. In localities where the temperature remains at or near 32 degrees for more than two or three days at a time it has been found necessary to have the beds covered in order to prevent the formation of ice. A layer of ice on top of the bed interferes very effectually with the operation of the filter, causing it to soon become airbound and eventually completely stopping the process. In addition, the cost of removing the ice

considerably increases the cost of operation of the plant, and makes it cheaper to cover the beds than to continually remove the ice.

3. MECHANICAL FILTRATION

As previously mentioned, mechanical filtration has made very rapid strides in this country and has far outdistanced sand filtrationin the number of plants and quantity of water filtered.

This has been very largely due to the suitability of this method to a large portion of the surface waters in this country since the mechanical filter will satisfactorily purify water which could not be purified economically by slow sand methods. It has become generally conceded that waters containing appreciable amounts of color or containing finely divided material in suspension may only be satisfactorily purified by mechanical filtration. In other cases, where either process might be satisfactorily used, mechanical filtration often has received the preference because of the fact that a mechanical plant, capable of handling an equal volume of water, will occupy a very much smaller space. In many instances also mechanical filters of the pressure type have been installed where it was found impossible to locate the filter plant at a point so situated as to provide sufficient head to properly operate the filters by gravity or where it was impossible or deemed inadvisable to pump water twice.

The cost of construction is and hence the fixed charges usually are much less per million gallons for mechanical plants than for slow or modified sand plants, although the operating costs are usually somewhat higher, the total cost being as a rule somewhat less.

In mechanical filtration plants the elements employed are filters of small area but using sand of larger effective size and operating under high rates of filtration. The filters are generally preceded by coagulation basins, although some coagulation basins are in substance merely mixing chambers. It is also necessary to maintain a supply of filtered water in order to provide against fluctuations in the rate of filtration and also to provide sufficient water for washing filters. In cases of extremely turbid waters, where much of the suspended matter has a high specific gravity, plain sedimentation is often employed to reduce the turbidity before the coagulant is added and thus reduce the amount necessary to properly clarify the water.

There are thirty-four mechanical plants listed in Tables 6, 7, 8

and 9, having capacities ranging from 1,500,000 gallons to 112,000,000 gallons.

The maximum capacity of the coagulation basins, shown in Table 6, is 1.66 times the daily plant capacity. The average capacity is, however, only one-fourth the average daily plant capacity. The maximum coagulation period shown in this table is that of the Charleston plant where the period for coagulation is 32 hours. This long period is made necessary by the high amount of vegetable stain in the raw water. The average color of the raw water at Charleston, as shown in Table 8, is 150 parts per million. On the other hand, the plant at Newport, Rhode Island, provides but 18 minutes for sedimentation. A glance at Table 8 shows that the average color and turbidity here are low. The average period of sedimentation for all the plants is from four to six hours.

Table 7 shows the number of filter units, their size, capacity, the rate of filtration, per cent of wash water required and data regarding the filter media.

The number of filter units depends, of course, upon the size of the plant, and the size of the unit. The unit size is limited by several mechanical factors, such as, amounts of wash water and air that can be economically applied and removed in cleaning the beds. There must too be a sufficient number of beds to enable one or two beds to be cut out for washing without raising the rate of filtration in the other beds beyond the safe limit. The tendency, however, has been in the past few years to gradually increase the size of the bed, as the mechanical difficulties have been overcome. The larger bed has several economic advantages over the small unit. The cost of construction is less in proportion to the size and the cost of operation per unit is relatively less, since no more labor is required to wash a 4,000,000 gallon unit than a 500,000 gallon unit.

The rate of filtration per acre in these plants has not been materially changed. At the Elmira plant, put into operation in 1897, the rate per acre is 150,000,000 gallons per day, and in the plant at Little Falls, placed in service in 1902, the rate is 125,000,000. This latter rate is the one commonly used today. At one or two plants a somewhat higher rate is being used. At the Hackensack Water Company's plant the filters are operated at rates as high as 180,000,000 gallons per day for short periods, and at New Orleans the rate is regularly 175,000,000 gallons per day. The increase in the filter unit area has, however, greatly increased the daily capacity

of the unit. In 1900 the average daily capacity per unit of from 100 to175 square feet in area was 500,000 gallons. Today, in the plant recently installed at Minneapolis each filter has an area of nearly 1,200 square feet and a daily capacity of 3.25 million gallons. In the mechanical plant proposed for the filtration of the Croton water supply at New York, each unit has an area of 1,700 square feet and a daily capacity of 4,000,000 gallons. The rate of filtration per acre per day remains at 125,000,000. The average size of filter unit, as shown in Table 7, is 579 square feet and has a filtering capacity of 1,600,000 gallons per day. The average rate of filtration per acre per day is 125,000,000 gallons.

The drainage systems used for the collection of the filtered water in the mechanical filter are much more complex than the collector system of the sand filter and so closely allied with the wash water system that it will be discussed under the latter head.

The loss of head through a mechanical filter is approximately from two to four feet when the filter is clean. This loss increases as the sand bed becomes clogged. It appears to be general practice to wash the filters when the loss of head rises to eight or ten feet.

The average thickness of a sand bed in a mechanical filter is less than in the slow sand filter. The variation is such, however, that the deepest beds—those at Charleston—are deeper than any of the sand filter beds, excepting those at Lawrence. The average depth of sand is 31 inches against 38 inches average depth of sand in slow sand filters. The average depth of gravel of 10 inches is practically the same as the average depth of gravel used in sand filters. The minimum depth of 6 inches, however, is only half the minimum depth of gravel in the slow sand filters. In recently constructed plants, 30 inches of sand on 8 to 10 inches of gravel is used.

The sand used in the mechanical filter is of a much coarser quality than that used in the other types of filter, and the grains are of more uniform size. The sand with the largest grain size is that used at the plant at Charleston. This sand has an effective size of 0.70 mm. The average effective size, as shown in Table 7, is 0.43 mm., and the lowest effective size is 0.32 mm. Owing to the development of methods of sterilization some of the most recently designed plants use a sand having an effective size of 0.65—0.69, and a uniformity coefficient of 1.65. This is a higher uniformity coefficient than that allowed ten years ago, which was about 1.30.

The per cent of wash water depends, other things being equal,

upon the frequency with which the filters are washed, and this in turn generally depends upon the amount of sediment in the raw water. There are, however, other factors, such as the nature of the suspended matter, the amount of alum used and the mechanical features of the wash water system, that cause variation in the per cent of wash water required, even though the turbidity be the same. Again, these features being equal, the amount of water required for washing will be decreased by complete sedimentation of the coagulated material so that the water passing to the filters is clear or nearly so. The maximum amount of wash water used is 7 per cent at Bristol. The minimum amount is 0.5 per cent and is used at New Orleans. It will be noted in Table 8 that at Bristol the sedimentation period is about 48 minutes, while at New Orleans the period is 24 hours.

In mechanical filters the system used for the collection of the filtered water serves also as a distributing system for the filtered water used in washing the filters.

There are three methods used for washing mechanical filters:

1. Washing with water applied at a velocity equal only to that obtained during filtration. Agitation of sand by mechanical rakes and claws.

2. Washing with water applied at a velocity of from 10 to 15 inches vertical rise per minute. Agitation of sand by air applied at a rate of from 2 to 5 cubic feet of free air per square foot of filter area per minute.

3. Washing with water applied at a velocity of from 24 to 30 inches vertical rise per minute. Agitation of sand by the high velocity at which the wash water is applied.

When the sand is broken up by mechanical stirring devices the strainer system consists of one or more cast iron mains with branch laterals. In the earlier types of tub filters the laterals radiated from a central cast iron collector. This arrangement produced an uneven distribution of water for washing and an uneven rate of filtration at various points in the bed. To remedy this defect other filters had the laterals arranged in concentric rings. Mechanical agitation is at present only installed in small filter plants, and has been otherwise superseded by air agitation. In plants using air agitation systems, the air is sometimes applied through the same strainer system as the wash water. In other plants a separate strainer system is used. The strainer system for the wash water consists of cast iron mains running lengthwise of the bed and brass

laterals laid 6 to 8 inches apart. The strainer cups are also usually spaced 6 to 8 inches apart on the laterals. It is necessary to use a special cup that will handle both water and air. In the more recently constructed filters the strainer systems are covered with concrete to the bottom of the strainer cups and these are in furrows formed by concrete blocks. These furrows are from 2 to 4 inches deep and are filled with coarse gravel or broken stone. When the separate system for the distribution of air is used, the distributing system comprises cast iron mains and brass tubing laterals. The laterals are usually spaced 6 inches apart and are not more than $\frac{3}{4}$ inch or 1 inch in diameter. The strainer cups are replaced by small holes or slots cut two or three inches apart and the whole system is placed above the water strainers, on top of the concrete ridges between the water laterals. The air laterals lie at right angles to the water laterals.

In the last few years it has been found that by increasing the velocity at which the wash water was applied, the sand bed could be thoroughly broken up and cleaned without the aid of either air or mechanical agitation. One of the first plants to be installed using this system was the plant in Cincinnati in 1908. The wash water at this plant is given a vertical velocity of 24 inches per minute. At other plants more recently installed this rate has been maintained. The amount of wash water required does not appear to be greater with this method than with air agitation. With the high velocity washing system the strainer system is composed of channels formed in the floor of the filter. These channels are covered with perforated brass plates laid in cement. Above the strainer plates is a bed of coarse gravel about 8 inches deep, and over the gravel to keep it in place, is a covering of brass screen cloth with ten meshes to the inch. The sand bed is placed on the wire cloth. At the proposed Jerome Park Filter Plant at New York, the strainer design places the strainer channels $12\frac{3}{16}$ inches apart (center to center) and requires a channel 3 inches wide and 5 inches deep. The strainer plates are in the form of an inverted V and the concrete blocks between the channels form furrows above the strainer plates 8 inches high and $9\frac{1}{2}$ inches wide at the top. These furrows are filled with gravel, and the wire cloth is fastened to the top of the concrete blocks. The wire cloth prevents the gravel from being blown out of the furrows by the force of the water, and also prevents the sand from packing into the furrows. The gravel and perforated plates produce a very uniform distribution of wash water.

This system also maintains a uniform rate of filtration over the entire bed.

4. DOUBLE FILTRATION

There are five cities in this country, and several abroad, where the water during purification is passed through two sets of filters. The first or preliminary filter is really little more than a scrubber and only removes the coarse suspended matter. The water is then passed either directly to the second set of filters, or passes through a sedimentation basin and thence to the final filters. The preliminary filters are usually similar to the ordinary type of mechanical filter. The difference, however, lies in the fact that in the common mechanical filter a coagulant is added to the water to increase the efficiency of the filter. No coagulant is used ordinarily with double filtration, Steelton, Pa., being an exception. The chief advantage in the method of double filtration lies in the increased rate at which the sand filters may be operated, and hence economy in space.

Table 1 shows the number of basins, the size and capacity of each basin and the period of sedimentation, for plants of this type. The plants at Philadelphia and Montreal, which are the two largest plants of this type, have no sedimentation, but the water passes directly through the preliminary filters and thence to the final filters. The average period of sedimentation at the three plants using this feature is less than the average period of sedimentation for the plants of the slow sand type, or the modified sand type. The average capacity of sedimentation basins used in this type is also much smaller than the average capacity of either of the other types mentioned. The average plant capacity, however, is much greater.

Table 9 gives the data concerning the double filtration plants, their size, number of filters, capacity, rate of filtration, thickness and size of the grains of the sand and gravel layers of both the preliminary and the final filters. The amount of wash water and the rate of its application for the preliminary filters and the average length of run for the final filters is also shown. The area of the preliminary filters is about the same as the area of the regular mechanical filter plants of equal size, varying from 360 square feet in the filters at Steelton to 450 at the plant in Wilmington. The capacity of the unit varies according to the size of the unit and the rate of filtration per acre per day. The average rate of filtration through the preliminary filters of the five plants cited, is 100,000,000 gallons

per acre per day. At Steelton, however, a rate of 172,000,000 gallons per acre per day is used. At Philadelphia, which has the largest filtration plant in the country, the rate is fixed at 80,000,000 gallons per acre per day. At Montreal, the latest plant of this type to be built, the preliminary filters are to be operated at a rate of 120,000,000 gallons per acre per day. This figure corresponds to the rate usually employed in mechanical filters. The preliminary filters used at Steelton consist of a 5 foot bed of finely screened anthracite coal over a gravel bed of 12 inches. The coal has an approximate effective size of 2.5 mm. At Wilmington the preliminary filters are of the Maigen type. In this type of filter no sand is used, but the water is forced upward through a bed of gravel, coke and compressed sponge clippings. The strainer system and the wash water systems used in the preliminary filters are the same as ordinarily used in plants of the mechanical type. The per cent of wash water and its rate of application is also the same as in plants using wash water with air or mechanical agitation.

The final filters used in the double type of filtration plants are similar to the ordinary slow sand filter, practically the only difference being in the rate of filtration. The rate used at Albany and Philadelphia is 6,000,000 gallons per acre per day, but since these plants were installed it has been found that rates as high as 10,000,000 gallons per acre per day can be maintained without impairing the efficiency of the filters. This rate will be used at the Montreal plant soon to be placed in operation.

The quality of the water treated in the plants using double filtration is inferior to the quality of the water treated in the other types of sand filtration plants shown in Table 4. The average turbidity at the five plants mentioned is 57.6, as compared to the average turbidity of 23.5 and 42.2 in the plants of the slow sand and modified sand type respectively. The average number of bacteria is also very appreciably higher. As previously mentioned the period of sedimentation is less in proportion to the capacity of the plant than either of the other two types, but the average length of run of the filter units is the same.

At three of the five plants sterilization is used as an adjunct to filtration. At Steelton, coagulation prior to filtration is also used, and, therefore, places this plant in a class by itself. Coagulation is resorted to in this plant because of the peculiar condition of the water to be treated, which is subject to extreme variations in character. The water contains at certain times of the year large

quantities of mine drainage, and, at other times, large quantities of suspended matter.

CLEAR WATER BASINS

We have reserved the discussion of clear water basins until this time, and will discuss this item of the plant regardless of whether the plant is of the mechanical type or the sand filter type, since no relation exists between the type of plant and its storage of the filtered water. The number of basins used for the storage of filtered water varies according to local conditions. This also holds true regarding the size of the individual basins. The average plant capacity for all plants is 33,800,000 gallons per day, and the average storage capacity is 16,600,000. The ratio between the average plant capacity and the average filtered water storage capacity is greater in plants of the mechanical type, than in plants of the slow sand type. This is made necessary by the amount of filtered water used for washing the filters. The largest storage capacity at any one plant in relation to the daily capacity of the plant is found at Lawrence, Mass. The plant at this city has a daily capacity of 7,500,000 gallons and a storage capacity for filtered water of 40,000,000 gallons. At the other end of the scale we find the City of Bristol, R. I., where the filtered water storage is only $\frac{1}{50}$ of the daily plant capacity. In the more recently constructed plants we find a much shorter period of storage than in the older plants.

STERILIZATION

The subject of sterilization has been brought to the attention of the public so constantly in the last five years, that it is not necessary to enter here into an historical account or any discussion of this latest means of purifying water. We will simply mention, very briefly, the various methods used to effect the sterilization of water.

Hypochlorite of calcium or "bleach," is the sterilizing medium employed almost exclusively in this country. At the inception of this practice it was customary to apply the hypochlorite prior to filtration. In some of these plants it was found that the amount of coagulant required could be materially reduced when hypochlorite was added. More recently, however, the tendency has been to apply the sterilization solution to the water after filtration as this reduces the possibility of aftergrowths and usually requires less hypochlorite.

At Brooklyn, Wilmington, Philadelphia and Niagara Falls experiments are at present being carried on using liquid chlorine as a sterilizing medium in place of the calcium hypochlorite. The use of this substance has many advantages over the use of bleach, as in some of the installations no mixing tanks are required, and the application of the sterilizing reagent is much simplified. As yet the application of this substance is in the experimental stage. The indications are, however, that the process will be even cheaper and much more easily regulated than hypochlorite.

At a few places in this country ozone has been used as a means of sterilizing water. This reagent is to be preferred from the aesthetic viewpoint, but the cost of ozone sterilization has thus far proved to be much greater than sterilization by the use of chlorine.

In several places in Europe experimental plants have been installed for the sterilization of water by ultra-violet rays. These sterilizing rays are produced by a mercury arc lamp of high potential, using quartz globes instead of glass. This process has not been tried out on a large scale in this country, and the cost of production on a commercial scale and the efficiency as compared with other methods are not known. The method is difficult to apply on a large scale as the water must be clear, fairly free from color and must come in close contact with the quartz plates. Up to the present time calcium hypochlorite is the reagent most commonly used for the sterilization of water in this country.

In conclusion let us review the changes which have taken place in filter practice during the period covered by this paper.

SAND FILTRATION

We find that in sand filtration the tendency has been to increase the period of sedimentation, the unit capacity and the rate of filtration. The size of the filter unit remains about the same, except in the modified type of sand filter, where there has been a gradual increase. There has been no change in the effective size or uniformity coefficient of the sand used, nor in the thickness of the sand or gravel beds. The storage period for filtered water in the slow sand type has been shortened, while for the modified and the double sand types it has increased. The greatest changes have been made in the rate of filtration. Of course these observations do not hold true in all plants now building, but the general tendency appears to be in the direction indicated.

MECHANICAL FILTRATION

The most conspicuous change that has taken place in mechanical filtration is the increase in the size of the filter unit, and, consequently, in the capacity of the unit. The rate of filtration has not changed, neither has the thickness of the sand bed. The thickness of the gravel layer, however, has been decreased somewhat. The other changes that have taken place are, an increase in the rate of application of the wash water, a reduction of the storage period for the filtered water and a slight increase in the size of the sand grains.

STERILIZATION

The modern methods of sterilizing water, particularly by the use of chlorine in its various forms, have had a marked bearing upon the latest filter construction. With proper sterilization methods it has been found that in many cases the rates of filtration may be increased and consequently the size and cost of filter construction may be reduced.

The use of sterilization in conjunction with filtration has come to stay and must be included in the advances made in the art of water purification during the past decade.

TABLE 1

Sand Filtration—Sedimentation Basins

NO.	LOCATION	DATE	PLANT CAPACITY (MIL. GAL.)	NO. BASINS	DIMENSIONS OF EACH BASIN	TOTAL CAPACITY (MIL. GAL.)	PERIOD OF RETENTION (HOURS)
			Slow Sand				
		1893					
1	Lawrence, Mass.	1902	7.5	0			
2	Yonkers, N. Y.	1904–9	16.0	0			
3	Washington, D. C.	1905	70.0	3		460.	158.
4	Greeley, Col.	1907	5.0	1	1400 x 500 x 8	30.	144.0
5	Putnam, Conn.	1907	0.75	0			
6	Pittsburgh, Pa.	1908	200.0	3	1325 x 500 x 15 1330 x 500 x 15 500 x 300 x 15	119.5	14.4
7	Providence, R. I.	1909	30.0	0			
8	Dover, N. H.	1909	2.0	1	53 x 39 x 8	0.12	1.5
9	Toronto, Can.	1910	57.0	0			
10	Reading, Pa.*	1911	3.0	0			
11	Ogdensburg, N. Y.	1912	4.0	0			
			Modified Sand				
12	Poughkeepsie, N. Y.	1872					
		1905	6.0	1	272 x 153 x 10	3.0	12.0
13	Lancaster, Pa.	1906	9.0	5		1.6	4.3
14	Springfield, Mass.	1909	15.0	1		40.0	64.0
15	Indianapolis, Ind.	1911	24.0	1		48.0	48.0
			Double Sand				
16	Albany, N. Y.	1899	30.0	1	600 x 382 x 9	5.7	5.0
17	Philadelphia, Pa.†	1904	240.0	0			
18	Steelton, Pa.	1908	4.5	1	32 x 12 x 10	0.03	0.15
19	Wilmington, Del.	1910	15.0	1	triangular	35.0	56.0
20	Montreal, Can.	1913	60.0	0			

* Bernhard Filters.

† Torresdale Filters.

Table 2

Sand Filtration—Sand Filters

NO.	LOCATION	DATE	PLANT CAPACITY (MIL. GAL.)	NUMBER OF BEDS	SIZE OF BED (DIMENSIONS)	AREA (ACRES)	CAPACITY OF BED	RATE OF FILTRATION (M. G. A. D.)	FILTER MATERIAL (SAND, INCHES)	GRAVEL (INCHES)	SAND (EFF. SIZE, MM.)	UNIF. COEF.	AVG. LENGTH OF RUN (DAYS)	BEDS COVERED
					Slow Sand									
1	Lawrence, Mass.	1902	7.5	4	Variable	0.75	1–1.8 3–1.5	1–2.5 3–2.0	54	12	0.25	2.5	25	1 yes 3 no
2	Yonkers, N. Y.	1904–9	16.0	6	4–225 x 150 2–180 x 124	4–0.75 2–0.5	4–3.0 2–2.0	4.0	42	12	0.25	3.0	30	4 yes 2 no
3	Washington, D.C.	1905	70.0	29	Variable	1.0	2.5	2.5	40	12	0.33	1.7	68	yes
4	Greeley, Col.	1907	5.0	2	210 x 165	0.79	2.5	3.0	24	12	0.25	3.0	?	no
5	Putnam, Conn.	1907	7.5	3	64 x 51	.075	0.37	5.0	36	18	0.36	2.7	21	yes
6	Pittsburgh, Pa.	1908	200.0	56	268 x 163	0.98	3.0	3.0	24	12	0.29	2.1	20	yes
7	Providence, R. I.	1909	30.0	10	250 x 174	1.0	3.0	3.0	48	12	0.29	2.3	24	yes
8	Dover, N. H.	1909	2.0	2	94 x 94	0.2	2.0	10.0	42	18	0.	?	60	yes
9	Toronto, Can.	1910	57.0	12	310 x 115	0.8	4.8	6.0	42	12	0.25	1.7	35	yes
10	Reading, Pa.*	1911	3.0	6	135 x 71	0.22	0.75	3.4	42	12	0.28	2.6	24	yes
11	Ogdensburg, N.Y.	1912	4.0	4	?	0.2	1.0	5.	36	12	0.30	3.0	50	yes
					Modified Sand									
12	Poughkeepsie, N. Y.	1905	6.0	4	2–196 x 72 2–127 x 113	0.3	1.5	2.3	48	18	0.29	2.4	62	yes
13	Lancaster, Pa.	1906	9.0	15	140 x 16	.05	0.6	12.0	24	10	?	?	15	yes
14	Springfield, Mass.	1909	15.0	6	260 x 91	0.5	3.0	6.0	42	12	0.35	2.7	32	yes
15	Indianapolis, Ind.	1911	24	6	?	0.8	4.0	5.0	32	10	?	?	20	yes

TABLE 3

Relation Between Quality of Raw Water, Sedimentation Period and Length of Run

NO.	LOCATION	DATE	QUALITY OF RAW WATER (PARTS PER MILLION)			PERIOD OF SEDIMENT (HOURS)	AVG. LENGTH OF RUN (DAYS)	COAGULANT USED	HYPOCHLORITE USED
			Turbidity	Color	Bacteria				
			Slow Sand						
1	Lawrence, Mass.	1902	3	4	23,500	0	25	0	no
2	Yonkers, N. Y.	1904	9	24	24,500	0	30	0	yes
3	Washington, D. C.	1905	106	0	6,400	158.	68	0	no
4	Greeley, Col.	1907	?	?	?	144.	?	0	no
5	Putnam, Conn.	1907	2	30	185	0	21	0	no
6	Pittsburgh Pa.	1908	40	5	8,000	14.4	20	0	yes
7	Providence, R. I.	1909	1	48	1,350	0	24	0	no
8	Dover, N. H.	1909	0	0	?	1.5	60	0	no
9	Toronto, Can.	1910	9	0	5,993	0	35	0	no
10	Reading, Pa.	1911	18		2,130	0	24	0	no
11	Ogdensburg, N. Y.	1912	0	2	250	0	50	0	no
			Modified Sand						
12	Poughkeepsie, N. Y.	1905	42	45	7,789	12	62	Alum	yes
13	Lancaster, Pa.	1906	58	12	12,800	4.3	15	"	no
14	Springfield, Mass.	1909	10	60	300	64	32	"	no
15	Indianapolis, Ind.	1911	30	?	600	48	20	"	no
			Double Sand						
16	Albany, N. Y.	1899	80	?	?	5	39	0	yes
17	Philadelphia, Pa.	1904	25	?	3,930	0	33	0	no
18	Steelton, Pa.	1908	70	10	6,200	0.15	40	Alum	yes
19	Wilmington, Del.	1909	68	15	49,000	56	27	0	yes
20	Montreal, Can.	1913	15	10	300	0	?	?	no

TABLE 4

Mechanical Filtration—Coagulation Basins

NO.	LOCATION	DATE	PLANT CAPACITY (MIL. GAL.)	NUMBER OF BASINS	DIMENSIONS	TOTAL CAPACITY (MIL. GAL.)	PERIOD RETENTION (HOURS)
21	Elmira, N. Y.	1897	7.0	0			0
22	Little Falls, N. J.	1902	32	1	130 x 43 x 42	1.32	1.3
23	Hackensack, N. J.	1904	48	1	400 x 270 x 21	11.5	6.0
24	Ithaca, N. Y.	1904	3	2		0.22	1.8
25	Charleston, S. C.	1904	6	2	306 x 153 x 10	10.0	32.
26	Harrisburg, Pa.	1905	12	2	45 x 33 x 16	0.36	0.7
27	Marietta, Ohio	1906	2.4	2		0.44	4
28	Cincinnati, Ohio	1908	112	3	2–400 x 200 x – 1–400 x 80 x –	22.5	5.
29	Columbus, Ohio	1908	30	6	135 x 125 x 20	15.5	12.0
30	Bristol-Warren, R. I.	1908	3.0	2	37.6 x 25 x 15	.1	0.8
31	Winfield, Kan.	1908	2.0	2	125 x 35 x 12	0.6	7.2
32	New Orleans, La.	1909	60.	4	325 x 275 x 14	60.	24
33	Louisville, Ky.	1909	36	2	1–340 x 160 x 20 1–340 x 80 x 20	12.	8.0
34	Sandusky, Ohio	1909	6	2	128 x 56 x 15	1.0	4.0
35	Toledo, Ohio,	1910	34	2	500 x 100 x 20	10.0	7
36	Wilkinsburg, Pa.	1910	12.5	2		3.0	6
37	Newport, R. I.	1910	7.5	1	80 x 25 x 16	.08	0.3
38	Kansas City, Kan.	1911	12	3	200 x 30 x 25	120	24
39	Cohoes, N. Y.	1911	10	2	79 x 41 x 17	0.8	1.0
40	Bangor, Me.	1911	8	2	140 x 42 x 20	1.5	4.5
41	Fort Worth, Tex.	1911	5	2	89 x 32 x 16	0.6	2.9
42	Ottumwa, Ia.	1911	4	2	60 x 45 x 16	0.5	3.0
43	Minneapolis, Minn.	1912	40	2	120 x 95 x 15	3.0	1.8
44	Grand Rapids, Mich.	1912–3	20	2	1–18 x 118 x – 1–118 x 89 x –	2.6	3.1
45	Niagara Falls, N. Y.	1912	16	2	124 x 55 x 21 2–89 x 62 x 28	2.0	3.0
46	Evansville, Ind.	1912	12.	3	1–89 x 32 x 28	25	5.
47	Fargo, N. D.	1912	6.	2	147 x 49 x 14	1.2	4.8
48	Rock Island, Ill.	1912	6	2	240 x 119 x 20	6.0	24.
49	Grand Forks, N. D.	1912	4.	4	2–140 x 60 x 10 2–140 x 20 x 10	1.6	9.6
50	Albany, Ore.	1912	3.	2	49 x 40 x 13	0.4	3.2
51	Minot, N. D.	1912	1.5	2	50 x 25 x 13	0.28	4.5
52	Trenton, N. J.*	19–	30	2	210 x 62 x 18	3.6	2.9
53	Evanston, Ill.*	19–	12	2	96 x 39 x 15	0.83	1.6
54	New York, N. Y.†	19–	320	5	Av. 713 x 118 x 25	76.	6.

* Under construction.

† Proposed but not to be built at present.

TABLE 5

Mechanical Filtration—Mechanical Filters

NO.	LOCATION	DATE	PLANT CAPACITY (MIL. GAL.)	NO. FILTER UNITS	UNIT SIZE		UNIT CAPACITY	RATE PER ACRE	FILTER MATERIAL (INCHES)		SAND		PER CENT WASH WATER	RATE APPLIED IN RISE PER MIN.	AIR WASH
					Dimensions	Area (sq. ft.)			Sand	Gravel	Eff. Size (mm.)	Un. Coef.			
21	Elmira, N. Y.	1897	7.0	21	13 x Dia.	132	0.33	150	30	6	0.56	1.43	2.8	14	no
22	Little Falls, N. J.	1902	32.0	32	24 x 15	360	1.0	125	30	12	0.44	1.47	3.5	12	yes
23	Hackensack, N. J.	1904	48.0	16	46 x 25	1,000	3.0	180	30	12	0.50	1.30	2.7	8.5	yes
24	Ithaca, N. Y.	1904	3.0	6	16 x 11	176	0.5	131	30	?	0.39	1.50	3.8	?	?
25	Charleston, S. C.	1904	6.0	12	15 x Dia.	176	0.5	100	50	12	0.70	1.30	4.0	13	no
26	Harrisburg, Pa.	1905	12	10	27 x 16	432	1.0	166	30	7	0.38	1.30	2.3	9	yes
27	Marietta, Ohio	1906	2.4	8	20 x 10	200	0.5	81	36	?	?	6.5	6.5	11	no
28	Cincinnati, Ohio	1908	112	28	28 x 50	1,400	4.0	125	30	7.5	0.32	1.20	3.0	24	no
29	Columbus, Ohio	1908	30	10	46 x 26	1,089	3.0	125	30	10.0	0.41	1.36	2.5	12	no
30	Bristol, R. I.	1908	3	6	15 x 12	180	0.5	125	30	6.0	0.45	1.74	7.0	14	yes
31	Winfield, Kan.	1908	2	4	18 x 10	180	0.5	121	48	?	?	?	4.0	?	no
32	New Orleans, La.	1909	60	10	53 x 27	1,431	6.0	175	36	8.0	0.35	1.65	0.5	24	no
33	Louisville, Ky.	1909	36	6	72 x 30	2,160	6.0	125	24	10.0	0.36	1.50	2.0	22	no
34	Sandusky, Ohio	1909	6	6	20 x 18	360	1.0	100	36	10.0	0.40	1.30	3.5	21	yes
35	Toledo, Ohio	1910	34	34	22 x 16	352	1.0	125	30	9.0	0.40	1.45	2.1	14	yes
36	Wilkinsburg, Pa.	1910	12.5	10	22 x 20	450	1.25	120	36	8.0	0.40	1.60	2.3	13	yes
37	Newport, R. I.	1910	7.5	6	24 x 145	348	1.25	156	27	18	0.40	1.70	3.5	16.5	yes
38	Kansas City, Kan.	1911	12	10	32 x 20	480	1.25	125	30	?	?	?	?	30.0	no
39	Cohoes, N. Y.	1911	10	10	23 x 15	347	1.0	100	24	12	0.40	1.65	4.0	?	?
40	Bangor, Me.	1911	8	8	24 x 18	432	1.0	100	27	9	0.59	1.25	4.5	12.0	yes
41	Fort Worth, Tex.	1911	5	4	25 x 20	540	1.25	125	34	11	0.39	1.42	?	14.0	yes
42	Ottumwa, Iowa	1911	4	4	24 x 14.6	348	1.0	125	27	9	0.50	1.40	3.5	12.0	yes
43	Minneapolis, Minn.	1912	40	12	51 x 23	1,173	3.25	125	30	8	0.39	1.65	0.5	24.0	no
44	Grand Rapids, Mich.	1912–13	20	10	36 x 23	738	2.0	118	30	8	0.39	1.60	4.6	24.0	no
45	Niagara Falls, N. Y.	1912	16	16	25 x 14.5	362	1.0	125	30	9	0.35	1.60	2.5	10.0	yes
46	Evansville, Ind.	1912	12	12	23 x 16	368	1.0	125	30	9	0.26	1.83	3.3	14.0	yes
47	Fargo, N. D.	1912	6	6	21 x 17	357	1.0	125	30	10	0.35	1.40	1.5	11.0	yes
48	Rock Island, Ill.	1912	6	6	21.5 x 17	365	1.0	125	30	10	0.32	1.65	1.2	14.0	yes
49	Grand Forks, N. D.	1912	4	8	18 x 11	198	0.5	110	30	6	0.39	2.1	4.0	?	?
50	Albany, Ore.	1912	3	6	22.5x 10.5	184	0.5	125	37	9	0.36	1.30	?	12.0	yes
51	Minot, N. D.	1912	1.5	3	14.6 x 12	181	0.5	125	34	30	?	?	3.0	13.0	yes
52	Trenton, N. J.	19–	30	16	30 x 24	652	1.87	125	30	10	0.39	1.65	?	18.0	yes
53	Evanston, Ill.	19–	12	6	36 x 23	846	2.0	125	30	8	0.65	1.65	?	?	yes
54	New York, N. Y.	19–	320	80	50 x 34	1,700	4.0	125	30	8	0.65	1.65	?	?	

TABLE 6

Mechanical Filtration—Relation Between Quality of Raw Water, Coagulation Period and Per Cent Wash Water

NO.	LOCATION	DATE	QUALITY OF RAW WATER (PARTS PER MILLION)			COAGULATION PERIOD (HOURS)	PER CENT. WASH WATER	COAGULANT USED	HYPOCHLORITE USED
			Turbidity	Color	Bacteria				
21	Elmira, N. Y.	1897	58	19	18,137	.0	2.85	Alum	yes
22	Little Falls, N. J.	1902	10	36	3,183	1.32	3.55	"	yes
23	Hackensack, N. J.	1904	15	35	2,000	6.0	2.75	"	yes
24	Ithaca, N. Y.	1904	72	20	7,150	1.8	3.8	"	?
25	Charleston, S. C.	1904	2	150	200	32.0	4.0	"	no
26	Harrisburg, Pa.	1905	54	9	8,239	0.7	2.34	"	yes
27	Marietta, Ohio.	1906	195	10	3,600	4.4	6.5	"	no
28	Cincinnati, O.	1908	170	10	10,000	5.0	3.0	Lime	no
29	Columbus, O.	1908	10	80	1,300	0.8	7.0	Alum	no
30	Bristol, R. I.	1908	70	33	10,000	12.0	2.5	Lime	yes
31	Winfield, Kan.	1908	?	?	?	7.2	4.0	"	no
32	New Orleans, La.	1909	525	?	2,800	24.0	0.5	Lime	yes
33	Louisville, Ky.	1909	272	0	14,017	8.0	2.02	Alum	no
34	Sandusky, O.	1909	75	20	2,200	4.0	3.5	"	yes
35	Toledo, O.	1910	120	45	16,000	7.0	2.12	"	yes
36	Wilkinsburg, Pa.	1910	35	26	8,430	6.0	2.3	"	yes
37	Newport, R. I.	1910	10	38	500	0.3	3.5	"	yes
38	Kansas City, Kan.	1911	5,350	?	?	6.0	?	"	yes
39	Cohoes, N. Y.	1911	?	?	?	1.0	4.0	"	yes
40	Bangor, Me.	1911	0	66	3,000	4.5	4.55	Lime	no
41	Fort Worth, Tex.	1911	?	?	?	2.9	?	Alum	yes
42	Ottumwa, Ia.	1911	1,000	?	2,500	3.0	3.5	"	no
43	Minneapolis, Minn.	1912	20	30	2,000	1.8	0.5	"	yes
44	Grand Rapids, Mich.	1912	40	35	3,000	3.1	4.6	"	yes
45	Niagara Falls, N. Y.	1912	10	5	5,000	3.0	2.5	"	yes
46	Evansville, Ind.	1912	375	9	2,490	5.0	3.3	Lime	yes
47	Fargo, N. D.	1912	100	10	3,000	4.8	1.5	Lime	?
48	Rock Island, Ill.	1912	130	40	2,500	24.0	1.2	Alum	yes
49	Grand Forks, N. D.	1912	100	5	3,000	9.6	4.0	"	yes
50	Albany, Ore.	1912	?	?	4,000	3.2	?	"	no
51	Minot, N. D.	1912	?	?	2,000	4.5	3.0	"	yes
52	Trenton, N. J.	19–	11	8	?	2.9	?	"	yes
53	Evanston, Ill.	19–	?	?	?	1.6	?	"	yes
54	New York, N. Y.	19–	?	?	?	6.0	?	"	yes

TABLE 7

Double Sand Filtration—Preliminary Filters

No.	LOCATION	DATE	PLANT CAPACITY (MIL. GAL.)	NUMBER FILTER UNITS	SIZE OF UNIT		CAPACITY OF UNIT (MIL. GAL.)	RATE OF FILTRATION M. G. A. D.	FILTER MATERIAL (INCHES)		SAND		PER CENT WASH WATER	RATE OF APPLICATION (IN. RISE PER MIN.)
					Dimensions	Area (sq. ft.)			Sand	Gravel	Eff. Size (mm.)	Un. Coef.		
	Albany, N. Y.	1910	30	16				80	24	12	0.45	2.00	4.0	12
	Philadelphia, Pa.	1909	240	120	60 x 20	1,200	2.0	80	12	30	1.0	?	1.0	12
	Steelton, Pa.	1908	4.5	3.	30 x 12	360	1.5	172	*60	12	2.5	?	?	12
	Wilmington, Del.	1908	15.	10	100 x 14.5	1,450	1.5	50	†	46	?	?	?	?
	Montreal, Can.	1913	60.	16	50 x 27.5	1,375	3.75	120	30		0.60	1.65		?

* Fine Coal—no sand. † Coke and Sponge clippings.

Double Sand Filtration—Final Filters

No	LOCATION	DATE	PLANT CAPACITY (MIL. GAL.)	NUMBER OF BEDS	SIZE OF BED		CAPACITY OF BED (MIL. GAL.)	RATE OF FILTRATION, M. G. A. D.	FILTER MATERIAL (INCHES)		SAND		AVG. LENGTH OF RUN (HOURS)	BEDS COVERED
					Dimensions	Area Acres			Sand	Gravel	Eff. Size (mm.)	Un. Coef.		
	Albany, N. Y.	1899	30.	8	258 x 121	0.70	4.2	6.0	36	12	0.31	2.30	39	yes
	Philadelphia, Pa.	1904	240.	65	43-235 x 140 22-253 x 132	0.75	4.5	6.0	30	16	0.32	2.5	33	yes
	Steelton, Pa.	1908	4.5	3	98 x 63	0.13	1.5	4.6	48	12	0.31	1.6	40	yes
	Wilmington, Del.	1910	15.	5	132 x 40	0.33	2.5	2	24	14	0.23	1.8	27	yes
	Montreal, Can.	1913	60.	16	340 x 56	0.37	3.75	10.0	27	12	0.30	1.65	?	yes

TABLE 8

Sand Filtration—Filtered Water Storage

NO.	LOCATION	DATE	PLANT CAPACITY (MIL. GAL.)	NO. BASINS	DIMENSIONS	TOTAL STORAGE CAPACITY (MIL. GAL.)	SUPPLY PERIOD (HOURS)
			Slow Sand				
1	Lawrence, Mass.	1902	7.5	1		40.	128
2	Yonkers, N. Y.	1904	16	2	1–60 x 45 x 11		
					1–96 x 60 x 24	1.27	1.9
3	Washington, D. C.	1905	70	1		15	5.1
4	Greeley, Col.	1907	5	1	224 x 224 x 12	5.0	24
5	Putnam, Conn.	1907	0.75	1	64 x 51 x 12	0.29	9.3
6	Pittsburgh, Pa.	1908	200	1	1,200 x 300 x 25	50	14
7	Providence, R. I.	1909	30	1		3.5	2.8
8	Dover, N. H.	1909	2	1		1.0	12
9	Toronto, Can.	1910	57	1	312 x 312 x 11	7.8	3.3
10	Reading, Pa.	1911	3	0		0	0
11	Ogdensburg, N. Y.	1912	4	1		1.0	6
			Modified Sand				
12	Poughkeepsie, N. Y.	1905	6	2		12.2	49.
13	Lancaster, Pa.	1906	9	1	198 x 100 x 12	1.65	4.5
14	Springfield, Mass.	1909	15	1	288 x 321 x 25	17	27
15	Indianapolis, Ind.	1911	30	3		30	30
			Double Sand				
16	Albany, N. Y.	1899	30	1	94 x 94 x –	0.6	0.02
17	Philadelphia, Pa.	1904	240	1	762 x 602 x 18–	50	5.0
18	Steelton, Pa.	1908	4.5	1	12 x 12 x 6	0.006	0.03
19	Wilmington, Del.	1908	15	1	364 x 212 x 6	6.0	9.8
20	Montreal, Can.	1913	60	1	426 x 229 x 20	8.0	4.0

TABLE 9

Mechanical Filtration—Filtered Water Storage

NO.	LOCATION	DATE	PLANT CAPACITY (MIL. GAL.)	NO. BASINS	DIMENSIONS	TOTAL STORAGE CAPACITY (MIL. GAL.)	SUPPLY PERIOD (HOURS)
21	Elmira, N. Y.	1897	7.0	2		10.0	35.
22	Little Falls, N. J.	1902	32.0	2	124 x 58 x 29	3.2	2.4
23	Hackensack, N. J.	1904	48.0	4	140 x 48 x 12	2.0	1.5
24	Ithaca, N. Y.	1904	3.0	1		0.5	4.0
25	Charleston, S. C.		6.0	1	165 dia x 12	2.0	8.0
26	Harrisburg, Pa.	1905	12	1	104 x 69 x 14	16.0	32.0
27	Marietta, Ohio	1906	2.4	1			
28	Cincinnati, Ohio	1908	112.0	1	400 x 400 x –	19.0	4.0
29	Columbus, Ohio	1908	30.0	2	219 x 214 x 16	10.0	8.0
30	Bristol-Warren, R. I.	1908	3.0	1		0.06	0.5
31	Winfield, Kan.	1908	2.0	2		2.3	28.0
32	New Orleans, La.	1909	40.0	2	310 x 262 x 14	15.0	9.0
33	Louisville, Ky.	1909	36.0	1	460 x 392 x 22	25.0	17.0
34	Sandusky, Ohio	1909	6.0	1	100 x 56 x –	.06	2.4
35	Toledo, Ohio	1910	34.0	1	250 x 250 x 12	5.0	2.3
36	Wilkinsburg, Pa.	1910	12.5	1		9.25	19.2
37	Newport, R. I.	1910	7.5	1		0.1	0.38
38	Kansas City, Kan.	1911	12.0	2		2.0	4.0
39	Cohoes, N. Y.	1911	10.0	1		5.0	12.0
40	Bangor, Me.	1911	8.0	2	106 x 62 x 12	0.5	1.5
41	Fort Worth, Tex.	1911	5.0	1	102 x 80 x 15	1.0	4.8
42	Ottumwa, Ia.	1911	4.0	1	300 x 150 x 15	4.5	27.0
43	Minneapolis, Minn.	1912	40.0	3	2–165 x 50 x 9		
					1–877 x 413 x 23	45.5	27.0
44	Grand Rapids, Mich.	1912–13	20.0	2	1–178 x 123 x –		
					1–122 x 36	3.04	5.0
45	Niagara Falls, N. Y.	1912	16.0	2		0.5	1.5
46	Evansville, Ind.	1912	12.0	1		1.8	3.6
47	Fargo, N. D.	1912	6.0	2	60 x 21 x –	0.2	.0
48	Rock Island, Ill.	1912	6.0	3	1–245 x 245 x 8		
					2–140 x 14 x 8	7.0	28.0
49	Grand Forks, N. D.	1912	4.0	1		1.0	6.0
50	Albany, Ore.	1912	3.0	1	62 x 50 x 14	0.31	2.5
51	Minot, N. D.	1912	1.5	1	63 x 45 x –	0.2	3.6
52	Trenton, N. J.	19–	30.0	2	1–256 x 67.6 x 10		
					1–48.5 x 42.3 x 10	1.2	1.0
53	Evanston, Ill.	19–	12.0	1	161 x 154 x 12	2.0	4.0
54	New York City, N. Y.	19–	320.0	1	55 acres	365.0	27.0

DISCUSSION

Mr. J. N. Chester: In the short experience of the speaker of some twenty-two years, he built some twelve or fifteen plants, all of which are still in operation, and believes that he was the first to advocate steel instead of wooden tubs, but because of that would not claim that the advent of the first steel tub began modern filtration, for no better results were gotten out of the steel tubs than the wooden tubs other than a little more comfort sometimes in their failure to leak and the feeling that the steel construction was an advancement. We have not yet altogether abandoned the use of steel tubs, nor have we abandoned the use of wooden tubs, although we almost universally design our filters with concrete tubs. Nevertheless within the last two years we have put in one filter plant with wooden tubs and another with steel tubs, and had good reasons for so doing. It is not necessary to explain why the steel tubs were employed in one of these cases further than to say that the plant was built for a steel company who rather wanted to use steel so that they could make the tubs themselves, and in that case we believe they will get just as good results from the steel tubs as they would get from concrete.

Prof. Edward Bartow: Modern filter practice has not yet become standardized. An illustration of this is certain installations which have been put in or are being put in in Illinois along the shore of Lake Michigan. The United States Naval Training Station has within two years completed a slow sand filter. The War Department at Fort Sheridan within about a year has put in pressure filters; and the city of Evanston has let a contract for mechanical filters. We are looking forward to an opportunity to compare the three as to their action on Lake Michigan water.

Dr. D. D. Jackson: Mr. Hill means to convey the idea that after the construction of the Little Falls plant, which was the first real *show* plant of its kind, mechanical filtration began to be in the ascendency.

Mr. M. N. Baker: The Little Falls plant has been generally accepted as marking a transition from empirical to rational design; or from the commercial plant developed by the filter companies to a plant based on principles established by independent scientific

investigations and designed to a greater or less extent by independent engineers—the filter companies coöperating. From this viewpoint it seems proper for Mr. Hill to state in his paper that the Little Falls plant marks a change to the modern system of filtration, if he means thereby mechanical filtration.

Mr. Frank L. Anders: We have had an opportunity in North Dakota to make a comparison between the older and later water purification systems and their development when used on the same water.

In 1894 the City of Grand Forks, located on the Red River of the North, passed through a typhoid fever epidemic wherein two hundred people lost their lives. A slow sand filter was at once installed. Taking into consideration the method of operation, the turbidity and bacterial contents and other characteristics of the raw water supply, it did not of late years furnish a satisfactory water supply. Three years ago they installed a mechanical filter plant, but due to improper handling of the water in the sedimentation basins, the plant is not an unqualified success.

In Fargo we have recently installed a mechanical filter plant which gives results entirely satisfactory when compared with those reported from similar plants. It seems, after a study of various plants, that the design and operation of the mixing chambers and sedimentation basin determine whether the filter plant will properly perform its functions or not. In two cases, with which the speaker is acquainted, the partial failure of the plants is in no way due to the filter apparatus or its installation, but it is due to improper design of mixing chambers and sedimentation basins and to lack of adequate methods of feeding chemicals to the raw water at the proper time and place.

PURE AND WHOLESOME WATER

By George A. Johnson

Water is second in importance only to air as one of the three fundamental necessities of human life. It comprises over three-fourths of the total weight of the human body, and every adult requires over three pints of drink each day to maintain this necessary proportion. It goes without saying, therefore, that water intended for drinking should be palatable, agreeable to the sight and smell, and free from matters which will exercise a debilitating effect, or actually cause disease in the human organism.

In forms of contract whereby a private corporation is to furnish water to a municipality it is the usual custom to specify that, among other things, the water shall be "pure and wholesome." This term is capable of many constructions, and in courts of law has always been a cause of lengthy discussion based upon the varied interpretations of what is really meant by this definition. Various individuals and scientific bodies have attempted to lay down so-called "Standards of Purity," that is, that the water shall be free from this and that, and contain not more than such and such amounts of this or that substance. Rarely do any two "standards" agree, except, perhaps, in so far as the physical characteristics of the water are concerned, and when the quality of a water supply is the bone of contention in a court of law it is not strange that each side can present a fair and seemingly logical argument based upon this or that standard. But all this is of slight assistance to the court who frequently is obliged to disregard both arguments and "standards," and proceed without their doubtful aid to a commonsense, nontechnical judgment.

DEFINITIONS OF "PURE" AND "WHOLESOME" AS APPLIED TO WATER

By pure water, if we are to be guided by the precise definition of the word, is meant water which is perfect, absolute and unadulterated; which is clear, clean and free from all foreign or vitiating material. By wholesome water is clearly meant water which is safe, the consumption of which is conducive to health.

Except as obtained by distillation, we cannot get perfect, absolute and unadulterated water which is free from all foreign material; but we can get clear, clean water, free from vitiating material and disease-producing bacteria, safe to drink and conducive to health. The line of practical distinction between the precise and the reasonable definition of the term must be drawn right there.

GENERAL COMPOSITION OF WATER

It is plain that pure water, as the term is commonly used, does not mean merely the liquid resulting from the combination of hydrogen and oxygen in the right proportions. Neither would such water be entirely acceptable for drinking purposes, for the presence of certain salts in all natural drinking waters makes them more palatable, and probably more healthful.

Every water supply primarily is derived from the rainfall, and from the time it condenses and begins to fall towards the earth it continues to absorb foreign matters, first, impurities from the air, and later such matters as it may pick up during its passage over or through the ground on which it falls. Some of these matters are dissolved and held by the water in that state, while others are naturally insoluble in water and are carried therein in suspension. These matters, both soluble and insoluble, may be organic or mineral in character.

Further than this, all surface waters are more or less polluted by the excreta of man and animals; sometimes necessarily so. These added foreign matters are also both organic and mineral, dissolved and water-insoluble in character.

Some waters, while safe to drink and coming from practically uninhabited regions, may be highly colored and muddy; others may be clear but very hard. There is almost no end to the combinations of the various constituents making up ordinary natural surface water supplies. Some waters are satisfactory in all ways except that they are muddy or colored; others are satisfactory in appearance but polluted by the drainage from isolated privies and barn yards; still others are foully polluted by the sewage of cities.

VALUE OF A SANITARY WATER ANALYSIS

Such standards of purity as have been tentatively advanced in the past, appearing for the most part in text books dealing with the general subject of water supplies, are purely technical in character. The ordinary sanitary analysis, on which such standards

are based, consists of a long list of determinations, both qualitative and quantitative, and the usefulness of many of them is supposed to lie in the information they afford with respect to whether the water has ever been polluted with animal excrement, and when and in what quantities. If it be assumed that water is free of pathogenic bacteria, and it can be shown that mere organic and mineral matter does not deleteriously affect the health of the consumer, what possible good can come from laboriously and expensively analyzing water for "oxygen consumed," "free ammonia," "albuminoid ammonia," "nitrites," "nitrates," "chlorine," and "total solid matter?" Why would it not be much better to restrict the ordinary chemical analysis to the really important, although simple, determinations, such as taste, odor, color and turbidity, in order to establish the range in its physical characteristics, and for suspended matter, iron and hardness to furnish a line on the really essential features of its chemical makeup?

How many water works are supporting laboratories at no small cost for the purpose of filling file after file with the results of chemical analyses which not only are incapable of definite interpretation, but which would be of no aid to the superintendent in the operation of the works if they were? In many cases such laboratory work is continued as routine because similar work is done in so many other water works laboratories.

Therefore, why not pay more attention to the recording only of such important data as will give clear, continuous and valuable information that any water works superintendent can understand, and which will serve as a reliable guide in the operation of the works under him? It is astonishing how much really valueless information is available on the nitrogen content of waters, and how comparatively little on color, turbidity and hardness. The filtration man does not strive for the removal of nitrogenous matters from water, *per se*, but he certainly bends every effort to the removal of color and turbidity, and very often, too, of hardness and iron. Let us now consider briefly of what real value is the chemical analysis so commonly carried as routine work in the water works laboratory, taking up each determination in the order in which it usually appears on the record sheets.

TEMPERATURE

Temperature observations are of some value in connection with the operation of a filtration plant, because it is well known

that all filters do their poorest work during cold weather; and where coagulating and softening chemicals are employed in water treatment it is equally well known that the coagulating and softening reactions are measurably slowed up by low temperatures, and accelerated by high temperatures. Temperature observations at different depths in ponds, lakes and reservoirs often furnish valuable information with respect to stratification, etc., and readily explain the reason for the periodic unsatisfactory appearance and taste of some waters, due to spring and autumn "overturn."

TURBIDITY

The ordinary citizen does not look with favor on a water which is turbid, that is, carries in suspension mud, silt and clay in quantities sufficient to impart to it a marked cloudiness or a distinct muddy appearance. It is not so much a case of whether such matter is actually injurious as that it is not agreeable to the sight, and promotes other aesthetic prejudices such as those against taking into the system so much actual mud and dirt. Therefore, in all up-to-date cities where the water supply is turbid it is the custom to treat it in some way before delivering it into the mains, in the endeavor to remove the turbidity and make it agreeable to the sight.

In some cities the means to this end are coagulation or sedimentation, or both, as at Kansas City, Missouri; Nashville, Tennessee; Richmond, Virginia, and St. Louis, Missouri. The majority of cities having turbid raw water supplies go still further, and also employ filtration through slow sand filters, as at Albany, New York; Delaware, Maryland; Indianapolis, Indiana; New Haven, Connecticut; Philadelphia, Pennsylvania; Pittsburgh, Pennsylvania; Providence, Rhode Island; and Washington, District of Columbia; but unless coagulants are used, or the period allowed for sedimentation is very long, or roughing filters employed to treat the water before it reaches the slow sand filters, such filters become over loaded and inefficient at times. Preliminary filters are a part of the slow sand filtration systems at Albany, Wilmington, Philadelphia and Pittsburgh, and coagulants are employed at Indianapolis, Pittsburgh and Washington. Other cities treat their muddy supplies with coagulants, and afterwards filter them through rapid sand filters, as is the custom at Altanta, Georgia; Birmingham, Alabama; Cincinnati, Columbus and Toledo, Ohio; Grand Rapids, Michigan;

Louisville, Kentucky; New Orleans, Louisiana; and Minneapolis, Minnesota.

Now whether the water be treated by plain sedimentation, coagulation and sedimentation or filtration, frequent turbidity determinations in the raw and treated water are of immense benefit. Certainly no filter superintendent can afford to be without them, for such observations serve as a sound guide to efficient and economical operation of the filter plant; yet it is only within comparatively recent years that this determination has been carried as routine in water works laboratories, and is not even now in some. Such data at hand allow the filter man accurately to fix the dose of coagulant that will properly and without waste prepare the water for filtration, and they allow the slow sand filter operator to predict with a fair degree of accuracy when it will be necessary to scrape a filter, which is of vital economic importance. The determination is one of the least time consuming, and least expensive of all those making up the ordinary sanitary water analysis, yet it is by long odds one of the most important.

COLOR

Many first class water supplies are highly colored. This yellowish color originates for the most part in vegetable extractions, and where swampy areas are drained these vegetable stains are usually prominent. Such color has no sanitary significance, but offends the aesthetic sense of sight, and it has become the custom in large cities to use every reasonable effort to effect its removal before the water is delivered into the mains.

The bleaching effect of sunlight is of some benefit, but is active for only a relatively shallow depth, and even this is dependent upon the initial color of the water. The writer has seen waters in northern England so colored as to look like strong tea. Sun bleaching in very shallow basins had little measurable effect in reducing this color. Some of the waters of Canadian lakes are highly colored with vegetable stain, and one in particular in the Algonquin Reserve, of which the writer has knowledge, although relatively shallow and in the summer fed but slowly by springs, consistently remains a dark amber in color.

Bacterial decomposition of the deposits on the bottom of some lakes deprives the lower strata of their oxygen, and such layers become highly colored. With the periodic appearance of the "overturn" in spring and autumn these colored layers are brought to

the surface, distributing the color throughout the entire body of water. Furthermore, under the anaërobic conditions sometimes existing at the bottom of lakes and ponds, iron is thrown into solution. On being brought into contact with air this iron is oxidized, imparting to the water a reddish brown color.

Under ordinary circumstances sun bleaching is actively felt for a depth of about one foot beneath the surface, and in a month's exposure to the sun's rays the color removal will amount to about 20 per cent.

By treating colored waters with chemicals all vegetable stains can be removed. Ozonization, and the use of oxygenated compounds of calcium, sodium or chlorine will effectively decolorize water, but their high cost is usually prohibitive were there no other objections to these forms of treatment.

Filtration of colored water through clean quartz sand will not effect measurable decolorization, and it is well known that without the aid of a coagulating chemical slow sand filters will not consistently remove more than about 20 per cent of the dissolved color in water. The most efficient and satisfactory method of water decolorization is by coagulation, followed by filtration.

The routine determination of color is therefore desirable, and an absolute necessity where its removal is aimed at. Without such information the superintendent has to work in the dark so far as adjustment of the dose of coagulant is concerned. This is costly, for if not enough coagulant is used the removal will be incomplete and unsatisfactory, and it is very easy to use too much where less would be enough, and thus waste money.

TASTE AND COLOR

Objectionable tastes and odors are sometimes naturally imparted to water through the growth of certain forms of microscopical life, and when such are recorded in the laboratory are followed by the taking of prompt measures to correct them, such as the application of copper compounds and the like to the affected water in the lakes and reservoirs on the collecting and distributing system. Such tastes and odors have no sanitary significance but are aesthetically objectionable.

In some cases certain industrial wastes discharged into the water above the intake will impart an offensive taste and odor to it. The routine test at the laboratory should furnish reliable data in this

line, and allow such odors and tastes readily to be traced to their source, and thus make their elimination possible.

NITROGEN

All organic matter naturally passes through a cycle of changes before arriving at the final stage of nitrate or saltpetre, and free and albuminoid ammonia, as determined in the chemical analysis of water, represent the nitrogenous organic matter in its earlier transitional stages. The presence in water of nitrogen in this form furnishes circumstantial evidence of its prior pollution, since fecal matter invariably contains such products. The word "circumstantial" is used advisedly, for the reason that vegetable matter from swampy areas, although remote from sources of animal pollution, often contributes nitrogen in these forms in considerable quantities. As such it would, of course, have no sanitary significance.

By some it is considered that the ratio between free and albuminoid ammonia serves as a fairly accurate guide in determining the character of the organic matter contributing it; and that a high free-albuminoid ammonia ratio coincident with low chlorides and nitrates characterizes vegetable organic matter; and, conversely, that high free ammonia with high amounts of chlorides, characterizes animal organic matter. In a very general way this is true, but since by chemical analysis one can obtain from vegetable matter precisely the same combinations in free and albuminoid ammonia, nitrites and nitrates, that come from the analysis of water polluted with animal excrement, the evidence furnished is certainly but circumstantial.

And after all of what sanitary significance is mere organic matter, whether animal or vegetable, in the absence of specific germs of disease? Eliminating the aesthetic phase, and the possible effect of imagination on the human organism, it actually has very little sanitary significance, as will be shown later on.

CHLORINE

The chlorine found in water is not of particular sanitary significance, but inasmuch as sewage and domestic wastes contain large amounts of salt, its presence in water supplies indicates that it may have come from such sources. The water supplies of seaboard cities, even when unpolluted, are normally higher in chlorine than unpolluted inland supplies, due to the salt blown in from the ocean. In certain inland localities unpolluted water supplies are

high in chlorine, due to mineral deposits in the soil. Therefore, like nitrogen, high amounts of chlorine in water merely furnish circumstantial evidence of dangerous pollution.

TOTAL SOLIDS

When a sample of water is evaporated to dryness the dry residue represents the total solid matter which the water originally contained. This includes, not only the matter in suspension which rendered the water turbid, but matters in solution. The results have little or no sanitary significance.

VOLATILE SOLIDS

When the dish containing the "total solids" is heated the so-called "volatile" solids are burnt up. These are supposed to represent the organic matters present in the water, and some analysts attempt to characterize these by their charred appearance and odor when burning. Such determinations have little or no value in water analysis.

HARDNESS

Water, in its passage over and through the soil, dissolves and picks up certain minerals, among the most common being lime and magnesium. These give to the water its hardness.

There are two kinds of hardness, namely, temporary and permanent. The carbonates of lime and magnesium, held in solution by the dissolved carbonic acid in the water, constitute the temporary hardness and may be almost completely softened by boiling. Waters which, in addition to dissolved carbonates, contain in solution calcium and magnesium sulphates, chlorides or nitrates, cannot be effectively softened by boiling. Such hardness is termed "permanent."

Hard water is objectionable for a variety of reasons. It wastes soap, and affects the skin unpleasantly; it is more or less unsatisfactory for general culinary purposes; and it produces scale in boilers, reducing the life thereof and causing a wastage of coal; and it is objectionable in some industries, such as paper mills.

It is difficult to set a maximum limit for the amount of hardness a water may contain and yet be considered satisfactory. In the lake cities a total hardness of 100 parts per million is considered satisfactory, yet such a hardness in Eastern Altantic cities would be considered unsatisfactory. At Columbus, Ohio, where the

total hardness of the raw Scioto River water ranged from 41 to 372 parts per million, and averaged 222 parts during the year 1912, the water is softened, and the endeavor is always to deliver to the consumers a water having a total hardness of 100 parts per million or less. In 1912 the actual total hardness of the Columbus tap water averaged 79 parts per million.

Hardness determinations are highly important, and should be carried as routine in all water works laboratories. By determining the total hardness and the alkalinity (the difference generally representing the permanent hardness) an excellent line is afforded on this important characteristic of water. The records are of value in settling discussions as to the advisablilty of softening the water; in soap consumption; on its utility for various industrial purposes, and on its suitability for steam raising. Where a coagulating chemical is used in the purification of a water supply it is indispensable, owing to the fact that a certain amount of alkalinity is required to decompose every grain of added coagulant, otherwise if the alkalinity be deficient, coagulation will be unsatisfactory and undecomposed coagulant appear in the treated water; an inadmissible condition. The sanitary aspect of hardness will be referred to later on.

IRON

Practically all natural waters contain iron. The soil contains iron in the form of sulphide or oxide. Being dissolved out in water it may be present as an oxide, a carbonate, or as "humic acid," the original organic compound which holds ferric oxide in solution.

Ferric oxide can be removed by sedimentation and filtration; ferrous carbonate by aëration through the opportunity thus afforded for the escape of carbonic acid; and if the iron happens to be in combination with organic acids, the addition of alkalies will break up the loose combination and liberate the iron.

Generally speaking, no water can be considered entirely satisfactory which contains more than about 1.0 part of total iron per million parts of water. Even a less quantity than this is desirable, as a taste is sometimes perceptible in water containing around one part of iron.

Some rivers are heavily polluted by iron wastes from mines, and from iron and steel industries. The amount of iron in many cases is so high as to require removal. In the Shenango River at New Castle, Pennsylvania, below the extensive iron and steel

mills at Sharon, the raw water carries at times as high as 200 parts per million of iron. This is practically all removed from the New Castle water supply by chemical treatment and filtration through rapid sand filters. At Pittsburgh in 1912 the raw Allegheny River water contained 4.6 parts per million of iron on an average, the range being from 0.4 to 120 parts per million. This is always reduced to less than one part by sedimentation and slow sand filtration.

It is clear from the above that the determination of iron is of importance in the analysis of water, and in numerous instances, at least, should be carried as routine.

CARBONIC ACID

The determination of free carbonic acid in water is of importance, as it is well understood that it is an active agent in the corrosion of metals, particularly iron and lead. "Red water" troubles are often to be laid at the door of free carbonic acid, in some measure at least, and where it is present in relatively large quantities steps are often taken to remove it by adding lime to the water.

Where coagulating chemicals are used, particularly where lime is not employed with the salts of iron and aluminum which are more commonly used as coagulants, the determination of free carbonic acid furnishes valuable information, as with each grain of added coagulant there is a corresponding increase in the amount of free carbonic acid.

Sanitary Significance of the More Common Constituents of Water

Eliminating from discussion for the time being all forms of bacterial and other microscopic life, let us consider the evidence bearing on the sanitary significance of the more common constituents of water, as determined by chemical analysis.

PHYSICAL FEATURES

Under this heading, of course, come taste and odor, color and turbidity. What effect on the health of the consumer have these features as applied to water?

A water heavily charged with mud will naturally possess an argillaceous or clayey taste and odor, the same being intensified on heating. This is not agreeable to many. Assume that a water contains on the average 100 parts per million of suspended matter.

In a year's time an adult will consume in this way about $\frac{1}{7}$ pound of such matter, or some 5 pounds in a lifetime. This quantity will go a considerable distance toward the "peck of dirt" a person is supposed to eat in the course of a lifetime, but in itself cannot be considered as having any sanitary significance.

Water which is naturally highly colored sometimes possesses a slight astringent taste, but such coloring matters, being vegetable stains for the most part, can have no deleterious effect on the health of the consumer.

Some waters possess offensive tastes and odors due to growths in them of certain higher forms of microscopical life, and due to the liberation by them of essential oils in the process of their development or decay. These are relatively small in quantity, and cannot in themselves actually cause serious disturbances in the body of the consumer.

Some waters are so heavily polluted with certain industrial wastes as to give them a highly objectionable taste and odor. Probably the most prominent in this line are waters tainted with the waste liquors resulting from the destructive distillation of wood and coal. Creosotes, phenols and similar compounds are especially offensive and far reaching. A very few drops of creosote will impart a marked taste to a gallon of water.

At Marquette, Michigan, trouble of this kind was encountered, and only overcome by moving the water works intake far out into Lake Superior, and locating it some 50 feet or so below the surface. It will be recalled that the waters of Lake Superior are not subject to periodic overturn, as are those of the remaining Great Lakes.

In some streams in Pennsylvania this sort of water pollution has become a serious nuisance. Warren, Pennsylvania, has experienced a great deal of trouble of this kind, and likewise New Castle, Pennsylvania.

At the latter place the creosote liquors came from the byproduct coke plant of the Carnegie Steel Company, located at Farrell, on the Shenango River, and some 20 miles above the intake of the New Castle water works. The waste liquors from this plant amounted to some 160,000 gallons daily, and the amount of creosotes and phenols to a maximum of about 200 pounds daily. Now it so happens that the minimum daily flow of the Shenango River at Farrell is about 15,000,000 gallons, therefore the creosotes equalled under these circumstances .000228 grain per gallon, or .0039 part per million. The theoretical dilution was 1:9000. A strong

creosote taste and odor was imparted to the water, and this, as was anticipated, could not be removed by moderate aëration, treatment with lime and sulphate of alumina, and subsequent rapid sand filtration. The difficulty was only overcome when the Steel Company impounded all of the wastes of the coke plant, and afterwards used them for coke quenching, in which process, of course, they were vaporized.

Now as to the sanitary significance of such substances in water. Let us assume that the 200 pounds of creosotes and phenols were all pure creosote. The medicinal dose of creosote may safely be taken at 10 drops. To get a single medicinal dose from water polluted as above it would be necessary for one to consume over 30 gallons of the water. Furthermore, creosote is not a cumulative poison, but is rapidly excreted through the pores of the body, leaving nothing behind.

Finally then, those physical characteristics natural to many surface waters which lend to them an unsightly appearance, or an objectionable taste and smell, are of actual injury only in so far as they may affect the individual imaginatively. This feature is not to be disregarded, however, for there is no doubt that many thousands of people actually have thought themselves into the grave. One of the first lines of commonsense water logic, therefore, is that drinking water shall be free from perceptible quantities of color and turbidity, and that it shall possess no disagreeable, or actually foreign, tastes or odors.

ORGANIC MATTER

Under this heading, although it may not be precisely correct, we will include all nitrogenous matter, such as free and albuminoid ammonia, nitrites and nitrates; and carbonaceous matter, such as "oxygen consumed" and the like; in short, all organic matter found in water, both of vegetable and animal origin, whether derived from human or animal excrement or from the wash of woods and fields. It is necessary at this point only to eliminate living bacteria from discussion. They will be considered later on.

There is nothing in the complex compounds of organic matter commonly found in water supplies which need give alarm to the water consumer. Prior bacterial decomposition of such matters, doubtless, is instrumental in producing certain ptomaines, which in sufficient quantity would exert in some degree a toxic effect on the human organism. But while such conditions might be conceived of

in sewage, in water, even after it has received sewage up to the limit of its powers of digestion, the dilution of such substances is too great to warrant serious consideration being given to this feature.

While it is aesthetically repugnant to conceive of a drinking water supply originating from crude sewage, yet sewage, if thoroughly treated with chemicals and filtered, may be made perfectly safe for human consumption. Consider in this connection the purification of Bubbly Creek water at Chicago. This creek, receiving the sewage of some 400,000 people, is in a practically continuous state of fermentation. In its raw state it is slatecolor and putrescible, and contains at least five times as much nitrogenous, and twice as much carbonaceous organic matters as the ordinary run of polluted raw river waters. The bacteria always range around 1,000,000 per cubic centimeter, and forms of sewage bacteria are always present in relatively large numbers. By coagulation, sedimentation, sterilization with hypochlorite of lime followed by rapid sand filtration, a clear and sparkling effluent was obtained during a test of the purification process refereed by the writer in 1908. The filtered water contained 8 parts per million of "oxygen consumed," 2 parts of free ammonia, 0.14 part of albuminoid ammonia, 23 parts of chlorine, but under 50 bacteria per cubic centimeter, and B. coli rarely ever present.

A short time after this purified water was turned into the stockyards the matter became the subject of litigation, the City contending that it was illegal to use water derived initially from such a foul source as Bubbly Creek, even though it was later purified. The testimony for the defense brought out some interesting points bearing on the potability of such purified waters, which, while free from dangerous bacteria, still contained high amounts of animal and vegetable organic matter of known sewagic origin. It was shown that the waters of the Seine at Suresnes and Ivry, and of the Norder Elbe below Hamburg, where Altona obtains its supply, are in more or less the same class of foully polluted waters, but are purified and made safe for human consumption, even though they still contain in large quantities organic matter of sewagic origin.

The prosecution endeavored to establish the fact that, even though the water was made pleasing to the eye and rendered practically free from bacterial life, the filtered product still contained dissolved organic matter in such quantities as would be likely to exert a toxic influence on persons drinking such water continuously. Evidence to combat this view was furnished, referring particularly to the

Report of the National Board of Health, Senate Doc. Second Session, 47th Congress, 1882–1883, Volume 1, part 2, page 201; Second Report of the Royal Commission on Sewage Disposal of Great Britain, 1902, page 27; Report of the Massachusetts State Board of Health, 1890, page 537, and other published documents.

Professor E. G. Smith of Beloit College testified that in his opinion the water as delivered from the Bubbly Creek filter plant was a more safe and usable water supply than the city supply derived from Lake Michigan; and Professor John H. Long, a noted toxicologist, and a member of the socalled referee board, a commission appointed by President Roosevelt to study and report on the effect of food preservatives, testified that the filtered water did not contain substances which are to be considered harmful, and that, while he was unable to state an exact maximum permissible limit, the amount of dead organic matter still remaining in the filtered water was well within the safe limit. Furthermore, he stated that there is absolutely no difference between organic matter coming from sewage and that coming from decayed vegetables, that the protein matters are the same, and that they yield the same decomposition products.

Still further evidence is furnished by the testimony of Count Le Couppey de la Forest, Secretary of the Commission d'Etude des Eaux of Paris, France, given in the case of the State of Missouri vs. the State of Illinois and the Sanitary District of Chicago, 1903, pages 4829, et seq. There he stated that the effluent of the sewage farms of Paris is drunk exclusively by all of the 200 to 400 workmen, and close watch on their health is kept by regular city physicians who report weekly upon the health of these men; and during the past twenty or more years, in fact since these sewage irrigation farms were first started, there has occurred among these workmen no case of typhoid fever, or cholera or dysentery or any other of the diseases which are water borne.

Without evidence to sustain the point how can it be concluded otherwise than that dead organic matter, in such quantities as are found in water, has not the slightest actual sanitary significance? Again we are forced to fall back upon the aesthetic phases. One who first looks at a foully polluted and stinking body of water naturally rebels at drinking it even after purification, and when he knows it cannot harm him. If he had no knowledge of its source he would accept it without protest. But how do the results of chemical analysis actually benefit him or anybody else when recording the free and albuminoid ammonia, the oxygen consumed,

the nitrites and the nitrates as being present in this and that amount?

CHLORINE

The effect of chlorine on the public health, in the quantities and as found in water, is nil. The average individual consumes at the table each day many times as much salt as is ever present in a drinking water supply.

HARDNESS

It is the contention by some physiologists that those constituents which make water hard are deleterious to the public health. In some cases this view would seem to have considerable merit. The traveler is unpleasantly reminded of the effect of abruptly changing from a soft to a hard water, and vice versa, but there are no statistical data to prove that in general the hardness of a water has any clearly defined effect one way or the other on the public health. Although it is strongly maintained by some that various specific diseases such as urinary calculi, goitre, etc., are produced by the continued use of very hard waters, the confirmatory data to prove out this view are lacking. It is much more probable that the effect of hard waters is really restricted to simple gastric and intestinal disturbances, which are temporary only in their effect.

IRON

The chief objections to iron in a water supply, from a sanitary standpoint, are its undesirable taste and appearance, when present in sufficiently large quantities. Where it comes from the source of supply it can readily be removed by aëration and filtration; and when it comes from the service pipes through the corrosive action of carbonic acid and other agents, corrective measures have to be taken before the water is delivered into the mains.

The sanitary significance of iron in water may be considered as nil, for when present in large amounts its undesirable taste would preclude its use.

MICROSCOPICAL EXAMINATIONS

Water supplies are examined for the higher forms of microscopical life as a routine procedure in but few places. In the majority of cases such examinations are carried on only at times when the water possesses objectionable tastes and odors, the endeavor at such times being to locate and identify the organism which is causing the

trouble. Knowing the kind of organism, it is relatively easy to destroy it at its source through chemical treatment.

Where water works systems include large impounding reservoirs or storage basins such examinations may, to advantage, be carried as routine, except, perhaps, during the cold winter months. With a continuous record of the kinds and numbers of microscopical forms common to a water it is possible to anticipate by prompt chemical treatment a heavy growth which otherwise would result in the production of offensive odors and tastes.

Aside from aesthetic objections due to the appearance of "slime" in the water, and of offensive tastes and odors, due to the growth of such microscopical life, and all preventable by promptly instituting proper chemical treatment, such higher forms of microscopical life have no sanitary significance.

BACTERIA

It is the almost universal custom in water works laboratories to make daily analyses of the water supply for total numbers of bacteria; in some the number of bacteria developing on special media at body temperature is also determined; and in many presumptive tests for B. coli are carried as daily routine. There is no question that the results of bacterial analysis are of more value in determining the hygienic quality of a water than the entire chemical and microscopical data laboriously and expensively obtained.

Bacteriology is a comparatively new science, and by no means a precise one. It is a matter of common knowledge that with the methods of analysis of today the bacteriologist can isolate and positively identify specific disease germs only with the greatest effort and difficulty, and even then it is of primary importance that their number and virulence be also known before the water can justly be condemned. The finding in water of germs known to be associated in one way or another with disease-producing germs furnishes valuable circumstantial, but nevertheless indefinite, evidence.

Sometimes the presence of comparatively large numbers of bacteria in water has no sanitary significance whatsoever. This is true even when the evidence is quite positive that among the number are forms whose best known habitat is the intestines of man and domestic animals. Waters draining uninhabited areas, and therefore far removed from opportunities of pollution, particularly where

the areas drained are swampy, sometimes show high numbers of bacteria.

The test for B. coli is the usual way the present day bacteriologist has of ascertaining the relative purity of waters, also of forming a judgment of the purity of an individual water. This organism is the normal inhabitant of the intestines of man and some domestic animals, and of course is always present coincidentally with the typhoid germ when a person is suffering from that disease. It is equally true that in the vast majority of cases where B. coli is found in water the typhoid bacillus is absent. Therefore, where B. coli is found the inference that B. typhosus is or may be present furnishes circumstantial evidence purely, yet because the typhoid bacillus may be isolated from water only with the greatest difficulty, and because the reverse is true of the colon bacillus, the presence or absence in water of the latter organism is looked upon as the surest index of sewage pollution available to modern water bacteriology.

But the colon bacillus found, even if the number of coli be large, may have come solely from the excreta of domestic animals, or even from fish, and such animals do not suffer from typhoid fever. Again, the bulk of the coli may come from the excreta of perfectly well persons, and where a water is contaminated with city sewage this is always the case. So its presence in water merely furnishes evidence that it has been polluted with animal excrement; that typhoid fever germs *may* be present, but no proof that they are.

A water may contain a few stray coli and yet be perfectly safe to drink, for they all may have come from domestic animals. Furthermore, coli may have entered a water months before, even accompanied by typhoid germs; but both of these organisms, being out of their natural habitat in water, quickly become attenuated and lose their virulence.

In judging a water on the presence in it of B. coli, it is necessary to possess a knowledge of the number of these germs and of their vitality, in order that it may be known whether the pollution is recent, in what relative amount, or if it occurred a long time in the past and the germs found represent the attenuated survivors of those which entered the water originally.

The numbers of bacteria in a water and the results of the test for coli have a definite, though limited, value. High numbers of bacteria and the persistent appearance of B. coli can only mean a dangerously polluted water. Not that it is actually unsafe to drink all of the time, but that at any time it may become so. Low

numbers of bacteria and no coli can only mean a water of high sanitary purity.

The absolute value of bacteriological examinations is difficult to express except in this manner. B. coli may be present in a water every day for weeks and months on end and the water be perfectly safe. At Cincinnati, Ohio, during the year 1912, daily tests showed B. coli in the filtered supply three times out of every four when 100 cubic centimeter volumes were examined; and once in every twenty times where one cubic centimeter quantities were tested, yet the typhoid fever death rate in Cincinnati for that year was 7 per 100,000 people living, one of the lowest typhoid death rates recorded for that year among the cities of the world. An ordinary drinking glass will hold about 250 cubic centimeters of water, so according to the results of the Cincinnati analyses B. coli was probably present in every glass of drinking water, yet the typhoid fever death rate among its consumers was exceedingly low.

Ordinary city sewage contains about 500,000 B. coli per cubic centimeter, hence, on a basis of 100 gallons per capita daily sewage flow, one person will discharge 190,000 million coli each day. On the basis of a stream flow of 3 cubic feet per second per 1000 population contributing sewage, such water would contain immediately after the entrance of the sewage 26,000 colon bacilli per cubic centimeter, or about 6,500,000 in every glassful. Increase the above stream flow 50 times. Assume that 90 per cent of the coli are removed by purification of the sewage before it enters the stream and the number of coli in a stream so polluted become 52 per cubic centimeter, and about 13,000 in every glassful. Then further assume that 90 per cent of these coli are eliminated shortly after entering the stream, through such agencies as osmosis, etc., and there remain 5 coli per cubic centimeter, or some 1250 in a glassful of water.

Now take, for purposes of discussion, a city wherein the annual typhoid death rate is 10 per 100,000 population living. About 100 persons would suffer with this disease to cause this death rate. Assume that the cases are evenly distributed throughout the year and that the number of typhoid bacilli discharged by them is equal to the number of coli. Assume also, of course, that no attempt is made to disinfect the typhoid excreta, and that it all enters the stream in a crude state; then in water so contaminated and diluted, as described above in the first case, and before the numbers of bacteria are reduced by purification or other agencies, there would

be 26,000 colon and 4 typhoid bacilli per cubic centimeter; and the ratio between the number of coli and the number of typhoid bacilli, under these assumed conditions, which are intended to be the worst one is warranted in imagining, would be about 7000 to 1.

The purpose of the above discussion is to show, in an elementary way, that B. coli may be present in water in large numbers but not necessarily be accompanied by typhoid germs, or prove that the water is dangerous merely because it does contain coli. It is a sure index of fecal contamination and indicates danger. Would it not be better to conclude, therefore, that water showing coli in any number, at any time, and under any set of conditions is to be considered suspicious and to require treatment? Coli will always be found where the typhoid germs are, even though the latter are infrequently present when the colon bacillus is found.

From a strict hygienic standpoint there are no "pretty good" waters. A water is either polluted or it is not. If polluted it must be purified. The danger may be, and is, greater in proportion to the degree of sewage pollution, but any degree of danger is not admissible in the public water supplies of the present age.

STANDARDS OF PURITY OF WATER

The absolute impossibility of fixing a standard of purity which will apply equally well to the water supplies of the four parts of the country is bound to bring the interpreter of the results of water analyses to the conclusion reached by the rustic individual looking on a camel for the first time, "There ain't no such animal!"

No water analyst of standing and self respect will report his results in terms of standards, yet as late as a dozen years ago the Department of Health of a certain state issued a bulletin setting forth simple (?) standards whereby the nontechnical individual could readily judge for himself whether the water was safe or not to drink. The requirements a water was obliged to meet in order to be safe were absolute freedom from odor, color or turbidity, nitrites, nitrates and albuminoid compounds, simple qualitative tests being described for the detection of each of these fatal defects. It was further pointed out that with the use of the microscope one could readily determine the presence of typhoid fever and cholera germs!

Now for relief let us review the opinions of certain eminent sanitarians on the question of standards of purity.

Nichols, in his book on "Water Supply" (1883) said that to fix a definite standard which will apply to all waters, and by which any

one can judge of a given water from the numerical results of analysis, is impracticable.

Doctor Drown, in the Report of the Massachusetts State Board of Health (1890) had this to say:

> Standards are relics of days in which the harmfulness of a water was supposed to be the direct result of the injurious action of specific substances found in it. The theory of today is that it is to the presence of micro-organisms in water that its harmful influence is due. The results of chemical analysis have their highest value in the light that they throw on the quality of the water from the standpoint of bacterial contamination.

Mason, in his book on Water Supply (1896) said:

> The term "standard" is doubtless a poor selection. A hard and fast standard is simply an impossibility. Results which would be considered satisfactory for one locality might be entirely inadmissible in another. Local standards are the proper ones by which to be guided, and it is to be regretted that local "normals" are not more frequently found on record.

The Commission on Additional Water Supply for New York City (Burr, Hering and Freeman) in its report of November, 1903, stated that the qualifications regarded as essential for the new water supply were:

1. Absolute freedom from pollution, or from organisms capable of producing disease or discomfort.
2. Freedom from odor and from noticeable turbidity and color.
3. Softness.
4. Freedom from iron in solution.
5. Freedom from substances liable to corrode metal work, in boilers or service pipes.
6. A cool and equitable temperature is desirable.

It is very certain that no higher standard of purity could possibly be set. It is perfection; but is it possible to obtain a water supply coming within these strict limits, especially in the volume required by New York City? The unhesitating answer must necessarily be in the negative.

Where water is derived from surface streams, as is the additional supply for New York City, it is impossible to obtain "absolute freedom from pollution" even by acquirement of the entire catchment area supplemented by strict sanitary patrol. Incidental and accidental pollution may occur at any time, but in small and doubtless insignificant amount. Absolute freedom from pollution in practical terms means merely that up to the practical limit pollution

shall not obtain. There is no surface water supply in the world that is absolutely free from the possibility of pollution; nor will there ever be.

The same thing may be said of the essential requirements calling for "freedom from iron in solution, and from substances liable to corrode metal work, either in boilers or service pipes." There does not exist a water entirely free from these defects. It is possible to find many which are relatively free from them, and, where present in considerable amounts, there are ways effectively of removing them. The terms must be taken relatively; not absolutely.

The Committee on Standard Methods of Water and Sewage Analyses of the American Public Health Association in its 1905 report states that "less attention than formerly is now given to the chemical analysis of water, because of the inability of the chemical methods to separate that portion of the organic matter which is of no sanitary significance from that which is associated with pollution or infection."

Thresh, in his "Examination of Waters and Water Supplies" (1904) points out the importance of inspection of the source of supply, and the fact that Gruber of Vienna and Flügge consider that careful inspection, carried out with the unaided senses, seldom needs to be supplemented by chemical, bacterial and microscopical examinations. Thresh states: "I am convinced that standards cannot be adopted for any waters," but considers that a water which gives no indications of B. coli in 10 cubic centimeters, streptococci in 100 cubic centimeters and B. enteritidis sporogenes in 500 cubic centimeters is so free at the time of sewage pollution as to be safe. The key to his tentative standard of purity is the relative number of these germs found in sewage, which he gives as follows:

B. coli communis	100,000 to 800,000 per c.c.
Streptococci	1,000 " 10,000 " "
Spores of B. coli enteritidis sporogenes	100 " 2,000 " "

The State Water Survey of Illinois (University of Illinois, State Water Survey Series No. 5.) suggested in 1908 certain provisional standards of water purity as follows:

Suggested Limits of Impurities

(*Parts per Million*)

CONSTITUENT		SOURCE				
		Lake Michigan	Streams	Springs and Shallow Wells	Deep Drift Wells	Deep Rock Wells
Turbidity		None	10.	None	None	None
Color		None	.2	None	None	None
Odor		None	None	None	None	None
Residue on evaporation		130.	300.	500.	500.	500.
Chlorine		5.5	6.	15.	15.	5.-100.
Oxygen consumed		1.6	5.	2.	2.-5	2.-5.
Nitrogen as	Free Ammonia	.00	.05	.02	.02	.02
	Alb. Ammonia	.08	.15	.05	.20	.15
	Nitrites	.000	.000	.000	.005	.000
	Nitrates	.00	.5	2.0	.50	.5
Alkalinity			200.	300.	300.	300.
Bacteria per c.c.		500.	500.	500.	100.	100.
Colon bacillus in 1 c.c.		Absent	Absent	Absent	Absent	Absent

Let us pause for a moment at this point and consider the meaning of the above figures, which indicate what foreign substances water from these various sources may contain and still be safe to drink. If the lake water should contain 5 parts of oxygen consumed, .05 part of free ammonia, .15 part of albuminoid ammonia and .5 part of nitrates per million, would it be as safe for drinking as that from streams which possess this standard, provided both came up to the same bacterial requirements?

During 1908, the year when the above provisional standards were adopted, the city water in Chicago (from Lake Michigan) often contained twice as much "oxygen consumed" and albuminoid ammonia as noted in the above standard for that water. The free ammonia was at times as high as 0.4 part per million, and coli were present in from one third to one half of the one cubic centimeter samples examined, yet the typhoid fever death rate for that year in Chicago was 15 per 100,000 inhabitants. Of course it might be said that if the lake water had contained the standard quantities of those constituents the typhoid death rate would have been lower.

What the table is really meant to show, however, is the normal content of these various waters, and allow the inference to be drawn that when these stated amounts are exceeded the water may be polluted. In reality this is what standards should be made to show; and they must all be governed by local conditions and as carefully based as those given above.

But of what real lasting value are they? Everyone knows that the streams of Illinois, like other states, are polluted, and that Lake Michigan is polluted. Do they go farther than showing the degree of pollution, and, after all, will ten disease germs in a glass of water do more real damage than one or two, other things being equal?

Turneaure and Russell, in their book on "Public Water Supplies" (1908) said:

> Desirable as it would be to have definite standards of water analysis that would apply to all waters, such are, nevertheless, impossible. The changing conditions under which various potable supplies occur make it altogether out of the question to have a standard that would be of general application. In the present state of the science there is even a lack of uniformity in interpreting results, some analysts placing more emphasis on one factor than on another. . . . The most that a chemical analysis can do is to prove the presence of organic matter that may be a source of pollution. It throws no light on the question as to whether the same is actually disease producing or not; even though sewage is shown to have polluted a water, this does not prove it to be absolutely dangerous; but of course if the possibility of pollution is present, all it requires is the accident of disease to start an epidemic.

Allen Hazen, in his book "Clean Water and How to Get It" (1907) has the following to say regarding hygienic standards of purification:

> In the last years there has been a well marked tendency for water purification methods to crystallize about certain standards. These standards are those in the different methods which serve to reduce the turbidity and color to inappreciable amounts, and which in general remove something like 99 per cent of the bacteria. . . . There is no final reason for such standards. They have been adopted by consent because they represent a purification that is reasonably satisfactory. . . . Such purification makes the waters of some of the most highly polluted rivers used for public water supply in the United States, as, for example, the Merrimack and the Hudson, as safe hygienically, and as satisfactory, in every way, as supplies drawn from far better sources.

It is apparent from the above that Mr. Hazen does not attach much importance to the effect of dissolved organic and mineral matters in water if the bacterial removal is high. He substantiates this view indirectly in his book on page 37:

> It is, therefore, both cheaper and more effective to purify water, and to allow the sewage to be discharged, without treatment, so far as there are not other reasons for keeping it out of the rivers. It seems unlikely that a single case could be found where a given and reasonably sufficient expenditure of money wisely made could do as much to improve the quality of a given water supply when expended in purifying sewage above, as could be secured from the same amount of money in treating the water. . . .

The general project of keeping all sewage out of rivers is attractive, . . . but it is not a practical proposition and it is not necessary.

WHAT IS "PURE AND WHOLESOME WATER"?

A water once polluted with animal excrement cannot, in the opinion of some, ever again be "pure and wholesome." It will still be tainted and unfit for human consumption. Such people imaginatively place themselves in an unfortunate predicament, for the vast majority of the water supplies of the world in the raw state are polluted in some measure.

In 1909 the City Council of Chicago passed an ordinance which makes interesting reading. It was worded as follows:

No person or corporation shall use water taken from the Chicago River or any of its branches, or from any body of water within the city of Chicago which is stagnant, or in which refuse, waste, garbage, sewage or any other material tending to destroy the purity of the water has been dumped, placed or discharged, or in any manner found, for domestic purposes or for watering live stock, or for use in the preparation of meats, poultry or provisions for the market which are intended for consumption, or for any other use whatever which endangers the public health.

Observe that waters which have received prior pollution are restricted from use. No mention is made of whether the restriction held good if the water were purified before consumption; simply that such waters should not be used at all. If such an ordinance should become a state law in Illinois, or any other state, how many cities would have to abandon their water supply, which in many cases would be the only available one?

Whipple in his book on "The Value of Pure Water" (1907) says:

Unquestionably the term "pure and wholesome water," as ordinarily used, relates to water intended to be used for drinking. Such a water must be free from all poisonous substances, as the salts of lead; it must be free from bacteria or other organisms liable to cause disease, such as bacilli of typhoid fever or dysentery; it must also be free from bacteria of fecal origin, such as B. coli. In other words, the water must be free from poisonous substances, from infection and even from contamination. Besides this, it must be practically clear, colorless, odorless, and reasonably free from objectionable salts in solution and from microscopic organisms in suspension. Moreover, it must be well aërated. Color, turbidity, odor, dissolved salts, etc., may be permissible to a small degree without throwing the water outside of the definition of pure and wholesome waters.

Now this is a fair and reasonable standard of purity for drinking waters, with a vital exception, namely, absolute freedom from "bacteria of fecal origin, such as B. coli"; and pollution with fecal matter, as "contamination must be considered as potential infec-

tion." In other words, if a water has been polluted with fecal matter it is contaminated with potentially infectious material; if B. coli are present in it the water is not pure and wholesome.

Now all this, unquestionably, must not be taken literally, for virtually all surface waters at one time or another become polluted with fecal matter and contain "bacteria of fecal origin, such as B. coli." Careful purification removes visible evidences of fecal contamination, but it is still present in reduced quantity in a dissolved state in the filtered water. The removal of B. coli by the filters is always practically complete, although the best filters of any type, none of them being selective in their action, at times pass a few coli which appear in the filtered water. There is no exception to this rule. Therefore, if Mr. Whipple's suggested standard were to be taken to mean absolutely what it says, it would be impracticable and impossible of achievement. It must be taken generally, and the highly necessary adjective "reasonable" be considered as prefacing the noun "freedom."

Perhaps the most conservative, and at the same time logical and well meaning interpretation of pure and wholesome water, is that of the Supreme Court of Pennsylvania (70 Atl. Rep. 870) which ruled that wholesome water should be:

> Reasonably clear from dirt, discoloration and odor, reasonably free from bacteria and B. coli and other infection or contamination which renders it unfit for domestic use, and unsafe and dangerous to individuals.

Note the qualifying adverb "reasonably" in the above ruling. Without it the definition, while unmistakable, is idealistic and without practical value. Yet we are still more or less in the dark. What is meant by "reasonably" clear and colorless, and "reasonably" free from bacteria and B. coli and other infection or contamination?

It is safe to say that no surface water, derived from a watershed which is populated, or even unpopulated or practically so, but open to accidental pollution, is entirely safe for drinking purposes as it flows in the stream or lake. The day is not far distant when public sentiment, supported by stringent legislation, will result in the compulsory purification of all surface water supplies, used for drinking purposes, by filtration as is the law in Germany, or by other efficient means.

In conserving the purity of public waters it is always well to do all that can be done within reason in the line of rendering clean the

catchment area and keeping as large a proportion of the sewagic wastes out of the water as is possible. All communities are forced by conditions beyond their control to discharge their wastes into the nearest body of water. The convenience of such communities and interests of public health demand the most speedy and convenient removal of such wastes from their immediate vicinity, and no other feasible means are offered than to discharge them into the nearest stream, wherein they will be dispersed and carried away, or into lakes where the facilities for high dilution may be availed of. Nevertheless, the disposal of the waste products of human and industrial development by discharge into running waterways used by other communities as sources of supply, cannot, *per se*, be considered in any other light than a deliberate violation of one of the most elementary hygienic laws.

The public water ways, lakes and rivers, large and small, have served in the past and will continue to serve as ultimate carriers of the wastes of human and industrial development of cities located upon them. The increasing demand of an ever increasing population compels a corresponding increased use of river and lake waters, and such waters in a pure state and suitable as drinking water supplies without some form of purification are rapidly becoming a thing of the past.

One of the first principles to be recognized in connection with the discharge of sewage into running waterways, and the use of such waters as sources of public supply, is that no practical method of sewage purification will remove absolutely all danger from pathogenic germs. In the construction of a sewerage system, however complete and tight, provision must always be made for emergency or storm overflows. In sewerage systems designed to collect all of the house wastes in one system of pipes, and all of the street wash and much of the industrial wastes in another system of pipes, it is the custom to provide emergency overflows at the pumping station which become operative in the event of disarrangement of the pumping machinery, or parts of the purification works, if such works are provided.

In combined systems, carrying in the same pipes the sanitary and industrial wastes and street washings, storm overflows directly connected to the river are always built in the system, and become operative at times of heavy storms when the capacity of the sewers becomes overtaxed. It is clear, therefore, that in any system of sewers it is impracticable to depend absolutely on all of the dan-

gerous material being kept out of the river above the purification works at all times.

In sewage purification works, operated in the most careful manner, some material of a character dangerous to health may often escape. Even if the final effluent of such purification works should be sterilized with some active germicide, danger still remains from the storm sewage, and from temporary disarrangement of the purification works.

The primary object of a sewage disposal plant is to render the sewage unobjectionable, and to purify it to as high a degree as is commensurate with the benefits to be derived under the existing conditions. Bodies of water which are of necessity subject to sewage contamination in any form cannot be considered as other than potentially dangerous when consumed without first being subjected to some form of purification.

The capacity of a stream to dispose of sewage without creating offense depends, of course, upon the initial pollution of the stream, its volume and velocity of discharge. If the stream receiving sewage is large enough, and the dilution of the sewage and the time allowed for natural purification to take place are great enough, no aesthetic nuisance will be created. It frequently happens, however, that so many cities are located on one stream whose task it is to suitably dilute the sewage of those cities, that the capacity of the stream, particularly during the warmer months of the year, becomes overtaxed, obnoxious conditions are established, and the waters of the stream transformed into an ill-smelling, unsightly and unsafe condition.

To ameliorate such a state of affairs, but more often to avoid litigation brought or threatened by riparian owners below, some cities have been forced to purify their sewage before discharging it into the stream; and owing to the proximity of one city to another, all of the cities have been driven to consider ways of obtaining a pure and satisfactory water supply from some other source, or to the purification of a badly contaminated water. Los Angeles is going 250 miles to get a pure mountain supply.

The ideal state of affairs, toward which all thinking sanitarians are working, is a condition whereby all communities are required first to purify their wastes to such an extent that the establishment and maintenance of obnoxious conditions in the body of water receiving the sewage will be precluded; and then require the purification of such waters before they are used for public supply. Rarely

are two problems precisely alike. In some cases the sewage must be purified to a greater degree than in others, dependent upon the initial pollution of the stream, its minimum volume and velocity of flow, and the distance to the next city, or, more precisely, to the next water works intake.

Public waters must continue to receive the sewage of cities, as already stated, and it is only reasonable that such wastes before discharged should be made as unobjectionable as is consistent with the surrounding conditions. That is practically all that any community is called upon, or should be required, to do. The idealist would exclude all waste from public waters; but where then would they be disposed of? All surface waters may be, and many necessarily are, polluted, some more than others, hence we must accept the inevitable and cut our remedial cloth according to the requirements in each case.

REASONABLE STANDARDS OF PURITY

Appended to this paper are certain statistics bearing upon the physical, chemical and bacterial character of various water supplies of this country. These data show the average character of the water supplies as delivered to the consumers in different parts of the country. A glance at this table is all that is required to show how widely diversified in character are the water supplies in different parts of the country. The physical and mineral features are of course controlled by the character of the gathering ground; the other features by the pollution.

Now almost all of these supplies show evidence of prior contamination. The mark is there but what does it signify? Compare Kansas City with New York. We know that the water supply of the former, with either its high turbidity or hardness, would not be acceptable to the water consumers of New York City, yet the bacterial results at Kansas City make a more satisfactory showing, and the typhoid fever death rate in the two cities was virtually the same in 1912.

It is unnecessary to go farther in a discusssion along comparative lines. A supply which is satisfactory in one city would be held as unsatisfactory in another, although both are safe to drink. Communities accustomed to turbid or colored waters do not instinctively rebel against them, but only after they have seen and drunk clear and colorless waters. With hard water it is the same, but in a less degree, for the householder is aware that here lies the reason

for high soap consumption, and the steam raiser objects because of the cost of keeping his boilers free from incrustation and corrosion. But in a general way that is all.

We must acknowledge that it is not feasible to obtain from surface sources public water supplies which are free from all evidences of sewage contamination, but there is no reason to doubt the entire feasibility of so purifying contaminated supplies that they will be safe and wholesome. Such purified waters will still contain in reduced quantity the original sewage matters, but are made satisfactory to all the senses, and from a physical and chemical standpoint may justly be accepted as reasonably pure and entirely wholesome waters.

As to the bacteria: no matter what their significance, as shown by the usual sanitary analysis, sedimentation and filtration will reduce their original number to a relatively small residual, and sterilization effectively will remove the last vestige of potential danger which the contaminated water originally possesses. Therefore, what matters it, within the limits of reason, how contaminated the water was originally, if by purification, which is called for in connection with practically all surface waters, we can obtain at moderate cost a clear and colorless water, one which does not possess objectionable tastes and odors, and one in which bacterial life is reduced to a practical minimum? Is such water not to be classed as "pure and wholesome?" It certainly may justly be termed "wholesome," and also reasonably "pure," since its consumption is conducive to health, even though the strict and generally accepted interpretation of the word will not allow us to term it absolutely "pure."

The writer lacks the temerity to set down a list of standards of purity for public water supplies; but after what has been said above he does not hesitate to say that in his humble opinion "pure and wholesome water" should mean water which is free from noticeable turbidity and color, offensive tastes and odors, and forms of bacteria known to produce disease. Waters which in their natural state or by purification cannot be made to comply with this standard are without the pale.

The writer submits that a water reasonably free from color, turbidity and objectionable tastes and odors is not impossible, or even difficult, of achievement; nor is it difficult to pass judgment on a water that does not comply with these requirements. With the bacterial requirement it is vastly different, for the reason that

modern methods of bacteriological analysis are not sufficiently precise and speedy to allow of the ready detection of disease germs in water. How then is it possible to meet this most essential requirement in the light of the existing bacteriological methods? Until the typhoid bacillus and other germs which may produce disease can promptly and certainly be detected in water, it cannot be done.

Take the existing methods of bacterial analysis and the tentative standards proposed to form a basis for a bacterial standard of purity. What do mere numbers of bacteria prove? Nothing except in a comparative sense. Somebody once set the limit for pure water at 100 per cubic centimeter, and this standard has received wide recognition; but because a water contains only 100 bacteria is no proof that it does not contain disease germs; merely may the inference be drawn that there is ten times less *chance* that it does than would be the case if the water contained 1000 bacteria per cubic centimeter.

So it is with the colon test. Some hold that a water which persistently shows the presence of B. coli when 1 cubic centimeter volumes are tested is a dangerous water; but if found only occasionally in 10 cubic centimeter volumes it is reasonably safe. Again we have the *degree* of pollution of all kinds, not the specific index of specific contamination.

Would it be heresy to say that B. coli may be found in a water day after day and month after month, even in 1 cubic centimeter volumes, and yet that water be perfectly wholesome and innocuous? Such a condition can be imagined, even realized, for to become a producer of typhoid fever there would be required among those persons contributing the coli persistently found in the water an individual suffering from typhoid or convalescent from that disease. Indeed, the coli might all come from the harmless excrement of domestic animals, the same being used as fertilizer on the watershed and washed into the stream at time of rains and thaws.

B. coli when found in water is a danger signal. There is no doubt about that. The more that are found, and the oftener they are present, indicates increased and continuous contamination. It does not prove; it furnishes circumstantial evidence that the water may contain germs of typhoid fever. The greater the pollution the larger must be the number of people contributing to the pollution. Hence by increasing the number of people the danger is proportionately increased, because of the greater number of individual possible sources of typhoid fever. Therefore the number of coli present in a

water is of significance, yet with one colon bacillus there may be a typhoid, and with a hundred, none.

In the New York water supply in 1912, B. coli was found in 10 per cent of the 1 cubic centimeter samples examined; in 3 per cent of the samples of the same volume at Cincinnati; at Columbus daily tests of this volume showed it to be present only on two occasions during 1912; and at Minneapolis and Pittsburgh it was never present. The typhoid fever death rates in those cities that year were 10, 7, 19, 11 and 6. What absolute proof is afforded by the above colon results with reference to the typhoid fever death rate, which, after all, is the surest index of the hygienic quality of a water supply? Shall we use the New York data for a standard, and require that B. coli shall not be found more than 10 per cent of the time in 1 cubic centimeter volumes of the water?

Where water is filtered and made satisfactory on physical grounds, there is absolutely no excuse for the persistent presence in it of living B. coli or typhoid fever germs when hypochlorites or other effective germicides are employed as a finishing touch in the purification process. But nevertheless if they do appear at times the water cannot, without other good reasons, be condemned as unsafe to drink.

Careful filtration followed by sterilization presupposes among other desirable features a water of high bacterial purity, and by these means, provided the purification processes are carried through with skill and continued vigilance, everything within the reach of modern practice has been done to remove the impurities it may have contained; and it is plain that such purified water cannot be denied a place in the class of reasonably pure and wholesome waters.

In closing this paper, the writer desires to call attention to the list of proposed tests for obtaining essential data with various types of water, which appeared in the 1905 Report of the Committee on Standard Methods of Water Analysis. For convenience this list is appended, and while the writer does not accept as necessary all of the tests therein tentatively offered, particularly as regards the routine determination of nitrogen, he is of the opinion that this list more nearly sets forth the real essentials of a sanitary water analysis than any he has knowledge of. He furthermore is aware that under certain local conditions certain tests, not usually of much value, should be carried as daily routine, such, for instance, as those for free and mineral acids and sulphates in surface waters in coal mining regions, etc.

Tests Proposed by the Committee on Standard Methods of Water Analysis (1905) for Obtaining Essential Analytical Data with Various Types of Waters.

	SURFACE WATERS					WATERS BEFORE AND AFTER TREATMENT BY			
	Clear	Colored	Turbid	Highly Polluted	GROUND WATERS	Slow Sand Filters	Rapid Sand Filters	Softening Plants	Iron Removing Plants
Temperature	+	+	+	+	+	+	+	+	+
Turbidity	+	+	+	+	+	+	+	+	+
Color	+	+	+	+	+	+	+	+	+
Tint and shade	0	+	+	0	0	0	0	0	0
Odor	+	+	+	+	+	+	+	+	+
Nitrogen — Organic	+	+	+	+	0	0	0	0	0
Nitrogen — Alb. Amm.	+	+	+	+	+	0	0	0	0
Nitrogen — Free Amm.	+	+	+	+	+	0	0	0	0
Nitrogen — Nitrites	+	+	+	+	+	0	0	0	0
Nitrogen — Nitrates	+	+	+	+	+	0	0	0	0
Suspended Matter	0	0	+	0	0	0	0	0	0
Iron	0	0	0	0	+	0	+	0	+
Calcium	0	0	0	0	0	0	0	+	0
Magnesium	0	0	0	0	0	0	0	+	0
Total Hardness	+	+	+	+	+	+	+	+	+
Alkalinity	+	+	+	+	+	0	+	+	+
Incrustants	+	+	+	+	+	0	+	+	+
Chlorine	+	+	+	+	+	0	0	0	0
Acidity	0	0	0	+	0	0	+	0	+
Free Carbonic Acid	0	0	0	+	+	0	+	+	+
Dissolved Oxygen	0	0	0	+	0	0	0	0	+
Putrescibility	0	0	0	+	0	0	0	0	0
Microscopical Exam.	+	+	+	+	+	0	0	0	0
Numbers of Bacteria	+	+	+	+	+	+	+	+	+
B. Coli Tests	+	+	+	+	+	+	+	+	+

Average Results for the Year 1912 of Analyses of Water Supplies as Delivered to the Consumers

CITY	METHODS OF PURIFICATION	PARTS PER MILLION																					BACTERIA		TYPHOID FEVER DEATH RATE PER 100,000 POPULATION 1912	REMARKS
		PHYSICAL CHARACTERS			NITROGEN AS				Oxygen Consumed	Chlorine	SOLIDS			HARDNESS				Iron	MAXIMUM FOR ANY DAY					Total per Cubic Centimeter	B. Coli. % of time present in 1 C. C.		
		Odor	Color	Turbidity	Free Amm.	Alb. Amm.	Nitrites	Nitrates			Total	Volatile	Suspended	Total	Alkalinity	Incrustants	Free CO_2		Color	Turbidity	Total Hardness	Alkalinity	Iron				
Portland, Ore.	None	None	0	0							27	10		11	7	4		0.8								17	
Rochester, N. Y.	None	None	0	0	.001	.088	.000	.01		2.0	92	37		100										300	0.0	12	
Seattle, Wash.	None	None	0	0	.015	.030	.000	.00	0.2	4.0	60	15	0	14	1	13		0.0						60	0.0	8	
Spokane, Wash.	None	None	0	0	.008	.006	.000	.01	1.2	2.3	175	60		154	130	24		0.9						10		17	
Worcester, Mass.	None	2*d*	1	0	.004	.066	.000	.00	1.6	3.0	44	18		8												42	
Baltimore, Md.	Sterilization	2*e*	7	188	.076	.205	.009	.60	4.1	4.5	183	44	123	44	41	3			15	2300	69	66			0.1	22	
Chicago, Ill.	Sterilization $\frac{1}{4}$	None	0	5	.000	.060	.000	.00	1.4	4.0					120									130	12.6	7	Normal Analysis
Kansas City, Mo.	Sed. and Ster.	None	0	60	.080	.180	.000	.12	3.8	25.0		71	325	208	148	60		0.1						90	1.0	12	
Milwaukee, Wis.	Sterilization	None	0	10	.028	.100	.000	.12	1.8	6.0	160	80		124	114	10		2.0						140		23	
Minneapolis, Minn.	Sterilization	2*p*	26	7	.092	.332	.000	.29		3.3	208	91			163				72	39		212			0.0	11	
New York, N. Y.	Sterilization	2*v*	20	4	.059	.158	.005	.20		3.1	75	25		38	32	6		0.5	80	100	47	42	3.3	79	10.0	10	
Omaha, Neb.	Sed. and Ster.			20	.058	.138	.000	.62	2.4	11.0				222	152	70				70	346	260		56	0.6	12	
Richmond, Va.	Coag. and Sed.	None	14	2	.017	.074	.001	.01	2.2	4.7	92	37		52	30	22			34	8		54		425	16.0	15	
St. Louis, Mo.	Coag. and Sed.		10	5	.035	.108	.003	.71		11.0	211				52			3.4						750		13	
Denver, Colo.	Slow and Rapid Filt	None	3	1	.013	.089	.000	.15		28.0	230	30		160	86	74		0.0	10	10	221	115	0.2	175		13	
Los Angeles, Cal.	Infilt. Gall.													261	200	61										12	
Philadelphia, Pa.	Slow Sand Filt.	None		1			.001	.22	1.8	4.7	72							0.1		51			1.2	44	5.5	12	
Pittsburgh, Pa.	Slow Sand Filt.	None	4	2	.005	.021	.001	.17	1.7	13.0				50	16	34		0.1	7	18	97	32	0.7		0.0	6	
Washington, D. C.	Slow Sand Filt.	2*e*		0	.020	.042	.001	.51		2.8	113			59	52	7				4	100	96		35	0.8	23	
Atlanta, Ga.	Rapid Sand Filt	None	3	0	.015	.017	.000	.06	0 9	2.3	33				6			0 2	20	1		9	0.4	2	18.0	35	
Bangor, Me.	Rapid Sand Filt.	None	7	0	.024	.069	.001	.03	6.8	1.5	67			39	4	35		0.1						55	0.5		
Cincinnati, Ohio.	Rapid Sand Filt.		10	0	.028	.047	001	.48	1.5	14.0	145		0	78	42	36		0.1		2	111	71	0.4	26	3.0	7	
Columbus, Ohio.	Rapid Sand Filt.	None	6	0										79	46	33			18	2	133	85		14	0.6	19	
Grand Rapids, Mich.	Rapid Sand Filt.	2*e*	11	0										124	79	45			16	0	269	218		29	13.0	31	December 1912, only
Louisville, Ky.	Rapid Sand Filt.	None	0	0	.018	.040	.000	.51	1.3	13.0	143	24	0	84	45	39		1.0	0	0	125	31	1.2	140	2.6	19	
Harrisburg, Pa.	Rapid Sand Filt.			0	0	.015	.027	.002	.22	0.4	2.7	114	29			26		56	0.0						14	2.3		

DISCUSSION

Mr. Rudolph Hering (by letter): Mr. Johnson's paper contains some plain talk and a common sense view of the matter he has presented. We have been led off the main road too frequently by irrelevant examinations and analyses of waters. Our citizens have been sometimes deceived in believing their water supply wholesome when it is not, and fearing some imminent danger when there was no ground for such fear.

What years ago was called a sanitary analysis of water, looks today almost foolish, unless it is accompanied by other analyses or examinations not then made.

Pure and wholesome water requires two chief conditions to be fulfilled; that is, the water must be pure and wholesome as regards its contents of both mineral and organic matter. A chemical analysis will determine the former condition. A full knowledge of the content of bacteria and higher plant and animal life, which inhabit or are contained in the water, will determine the latter. If, besides being pure and wholesome, the water is to be pleasant and palatable for general use and consumption, a third condition should be satisfied, which we may call a physico-chemical analysis, to determine the color, turbidity, taste and odor.

The temperature of water as supplied to a community will be given much more attention in the future than in the past. To supply a cool water to our houses in warm weather will not only be wholesome, agreeable and economical to the occupants, but a cool underground storage will act strongly in favor of preventing the growth of pathogenic and some other objectionable organisms. In Europe the question of temperature of water supplies is already one of important consideration, particularly in Germany. The public reports state that in Hamburg filtered river water is now mingled with ground water in about equal proportions, chiefly to reduce the summer and increase the winter temperature of the water supplied.

If water is colored by vegetable stain, the color can be removed not only by sun bleaching, if the conditions are favorable, but by chemical means in a wholly unobjectionable way. As such a color implies no unhealthful but only an aesthetic condition, it is generally a question as to whether the community will pay the cost of removing it or not. The same may be said regarding some tastes given the water by algae and other organisms which inhabit chiefly lakes, ponds and reservoirs from which the supply is taken.

To a certain degree, the question of hardness of the water is also one of willingness to pay for a softening plant. No one will deny the advantages of soft water. But unless the hardness is considerable, we have very often met the opinion that the improved condition is not worth the cost.

The pollution of water by bacteria is however a real danger and is the chief sanitary cause of rendering water impure and unwholesome. All necessary analyses and examinations to determine the character of such pollution and all works necessary to remove such dangers are therefore a legitimate field of investigation, of design and of operating the works.

Here too, however, there has been much false alarm, because nearly all of the bacteria found in water are not objectionable. In fact nearly all are useful and almost necessary, in order to change decomposable organic matter into unobjectionable mineral matter. There was a time when some persons would not drink water that contained but a few bacteria and therefore confined themselves to other beverages. It was not generally known that milk, which was still pronounced satisfactory, contained up to 10,000 bacteria to the cubic centimeter.

Later, a discrimination was made between harmless water bacteria and those which come through the human body when it is diseased and which after entering other bodies, perhaps through the water supply, would produce the same disease. Attention was called to the colon bacillus indicating intestinal discharges. When the water contained colon bacilli, it was condemned.

Yet this bacillus is contained in the intestines of every human being, in animals and birds, on the entire earth, excepting only, according to report, far up in the Arctic region. When a child is born its intestines do not contain colon bacilli. It is nourished by mother's milk. Not until colon bacilli enter the organism through the mouth is the child, it was said, able to digest more complex foods, and this help to digestion remains with the body throughout its entire life. As the colon bacillus indicates intestinal discharges, it is for this reason that it indicates the possibility of real danger, as other and dangerous bacteria may have been discharged from the same bodies.

The germs of the so called water borne diseases, such as typhoid fever, dysentery, etc., are those which should be excluded from water supplies at every cost. A death caused by typhoid fever transmitted by a city's water supply is as much a death as that

caused by an accident on any other city work for which damages may be collected. We should therefore endeavor with all our skill to separate the essential from the nonessential requirements in our water supplies and to use all possible effort to place every safeguard around those now known to be essential.

It is therefore desirable that we discriminate between the real and the imaginary causes of impure and unwholesome water and concentrate our investigations in the directions which are of most use and most value, which Mr. Johnson has so well pointed out.

Mr. George W. Fuller (by letter): This paper on "Pure and Wholesome Water" has been written by Mr. Johnson from a rational viewpoint with which the writer is in sympathy. He wisely makes no attempt to exploit so called standards which at best are of limited value, but he makes a plea for the practical data which the analyst can supply to those who are obliged to judge of the quality of a water. His discussion is from a broad practical viewpoint and should be of much value for reference by those who have from time to time to deal with this general proposition.

The methods of chemical analyses practiced in England for more than a generation and in Massachusetts and other eastern states until quite recently, if not at the present time, were found by the writer to be utterly inadequate and unsuitable for recording practical data when he undertook in 1895 a study of the hard and turbid Ohio river water from the standpoint of its purification.

There are no points set forth by Mr. Johnson to which the writer takes special exception. On the whole the statements are well balanced and in accordance with the facts as the writer knows them. Bacterial analyses of water are capricious data with which to work and much care has to be exercised in drawing proper conclusions from the data of this kind as ordinarily obtained. The comments of Mr. Johnson as to B. coli are particularly interesting as they throw light on a question which is much mooted and which is scarcely capable of the unqualified deductions sometimes attached to results of the coli test.

There are a few notes which the writer has jotted down in reading this paper and which may perhaps be of some interest to those who follow such work. They are not set forth in any arbitrary way, but are mentioned in hopes of promoting a thorough discussion of the general subject.

Color. It is the writer's present practice to endeavor to secure

filtered water in which the color does not exceed ten parts per million. In connection with mechanical filters at Little Falls, N. J., it formerly was the custom to keep this color to about 5 parts, not because a 10-part water was objectionably colored, but on account of the effort to secure as high bacterial removal as practicable. The use of hypochlorite of lime has modified the writer's practice as to this limit of the color sought in the effluent of purification plants.

Tastes and Odors. These data are not ordinarily obtained with sufficient care in the case of many reservoir waters. And a careful study of such information in the opinion of the writer would be preferable to making many albuminoid ammonia tests on some waters.

Dissolved Oxygen. This determination seems to be made more particularly in connection with streams which receive more or less sewage. The value of such tests on large reservoir waters is greater than hitherto has been appreciated, particularly in connection with waters which stratify and where it is desired to secure water as free from objectionable tastes and odors as practicable. Some writers state that sewage should not be allowed to enter a stream so as to bring about a dissolved oxygen content less than that of about 70 per cent of the oxygen necessary for saturation of the water at a given temperature. This socalled standard, as is well known, is considered to be too drastic by the writer, but its interpretation could no doubt be rated more correctly if further data were available as to the oxygen content of many surface waters.

Chlorine. There are a number of surface waters as well as some ground waters in which the chlorine at times approaches and even exceeds the point where it is distinctly noted by taste. This limit varies with different waters, apparently in accordance with the total amount of mineral matter in the water. In ordinary waters it appears that salt can be tasted when the chlorine is found in amounts in the vicinity of 250 to 300 parts per million.

Hardness. Water softening seems to be more of a proposition for industrial plants than for the ordinary municipal plant. However, there are a number of plants where hardness data have been obtained on an extensive scale, particularly at Columbus, Ohio.

At Grand Rapids, Mich., the water softening and filtration plant was developed on the basis of reducing the total hardness of the water from about 250 parts per million to about half of that figure. The latter is about what is found in the water of Lake Michigan and has been referred to by some as the "Lake Michigan" standard.

It is believed by the writer that for many communities it is unnecessary to go to the expense of softening the supply to a lower figure than about 125 parts per million. At Grand Rapids it has been found ordinarily that the water can be softened and decolorized by the use of lime at less expense than would be involved in securing decolorization by the use of sulphate of alumina. To accomplish this desirable result, it is necessary to apply lime so as to remove a substantial portion of the magnesia in a form available for coagulating and decolorizing purposes. This has caused the total hardness at Grand Rapids ordinarily to be 80 to 90 parts per million.

Iron. Iron determinations are of much importance in connection with some ground-water supplies which contain this element in a soluble ferrous condition that is converted to an insoluble red precipitate upon exposure to air. At a slower rate such oxidation can take place apparently when there is only a small amount of oxygen in the water. This matter has received some careful study in connection with socalled "red water" problems and means of controlling the same through the use of quicklime or soda ash to eliminate the free carbonic acid in the water.

It is ordinarly found that well waters are liable to produce a precipitate of iron, and the amount which causes the precipitate to appear may be roughly taken as 0.5 part per million. The amount of iron needed to form a precipitate varies with the composition of the water and the form in which the iron is present. In some instances no precipitate forms when the amount of soluble iron reaches about one part per million, and in other cases a precipitate begins to form when the amount of soluble iron reaches about 0.25 part.

Mr. J. W. Ellms (by letter): In this paper Mr. Johnson has laid bare the weakness of sanitary science in its efforts to interpret the significance of the data obtained in the examination of water. While sympathizing to some extent with his pessimism as regards the unsatisfactory state of our knowledge on this subject, and of our inability to mathematically prove whether a water is or is not pure and wholesome, nevertheless, it appears to the writer that a more optimistic view can be taken of the matter without sacrificing our integrity as scientists. It can hardly be denied that sanitarians are constantly distinguishing between pure and impure waters, and that they do so successfully despite the varied and complex character of the data set before them.

No satisfactory discussion of this question is possible unless there

is an agreement upon the definition of a "pure and wholesome water." Mr. Johnson, the writer believes, has correctly defined what is a common understanding of sanitary purity for drinking water, viz., "water which is free from noticeable turbidity and color, offensive tastes and odors, and forms of bacteria known to produce disease." So far as the tests which are used to detect objectionable physical properties are concerned, the writer believes them to be fairly adequate for the purpose. Natural waters may possess undesirable properties in varying proportions, and towards them different persons will have varying degrees of aversion. Herein lies the difficulty of strictly defining the limits for those qualities which offend the aesthetic sensibilities of the individual.

The value of many of the chemical tests taken separately is slight, but considered collectively and in combination with the information supplied by the bacteriological and physical tests, they throw much light on the past history and present condition of the water. Certain of these chemical tests, as Mr. Johnson has stated, are invaluable, especially where the operation of purification plants is dependent upon a knowledge of the amounts of certain constituents, as for example the degree of alkalinity of a water in plants employing chemical coagulants. Even the nitrogen content of the water, knowledge of which Mr. Johnson seems to believe, is particularly useless, is not without value in classifying a water and determining its general character.

From the hygienic standpoint the determination of the purity and safety of a water for drinking purposes is most difficult. The inadequacy of bacteriological methods must be admitted. However, there is no reason for discarding the only available methods for obtaining information, merely because these methods do not furnish all the knowledge that is desirable. Most of the evidence obtained is purely circumstantial. Bacteriological technique does not permit of easy and rapid methods for the isolation of disease producing organisms. Nor is it by any means certain that all of the water borne diseases are known. Pathological conditions in the human body are probably produced by organisms of which we at present have no knowledge. These organisms may have water as their natural habitat, or they may become adjusted to such an environment. Hence the difficulty of establishing the purity of a water unless our technique provides means for the identification of all known pathogenic organisms. In lieu of direct proof, our

ignorance forces us to resort to circumstantial evidence, which often is of the most convincing character.

The writer has a great deal of sympathy for Mr. Johnson's contemptuous attitude towards the sanitary significance, or rather lack of it, attached to the Bacillus coli. This organism is probably harmless in itself, and yet its frequent association with other "vicious and disorderly" bacteria, has given it such a bad name that it often suffers on account of the company it keeps. Its presence is not prima facie evidence that disease producing organisms are associated with it. Nevertheless, its presence in a water, when taken in connection with evidence obtained from other sources, can usually be interpreted properly and with a fair degree of correctness.

The chemical, bacteriological and microscopical data obtained by the usual methods of examination do afford a basis for forming a fairly correct opinion as to the sanitary quality of a water. If the knowledge gained by these tests is supplemented, as it should be when possible, by information relating to the sanitary conditions surrounding the source of supply, then one is possessed of all the knowledge about the water that can be obtained. By intelligent interpretation of this information a fairly correct judgment of the character of the water is possible.

Mr. W. U. C. Baton (by letter): The subject of this paper has caused a great deal of discussion. There is little wonder that the court finds itself in a quandary when contracts containing this clause come up for legal decision.

An engineer would not think of specifying a steel for structural purposes as strong and serviceable, and stop there. Such specifications would be very indefinite, but the clause "pure and wholesome" in a water contract is equally so. Even when the qualification "reasonable" is added, matters are not much improved. The clause has to be interpreted and defined sooner or later; why not do it at the start?

If we have any idea at all what we want in a pure and wholesome water, we have enough of an idea to state it in a manner more intelligent to all concerned.

The writer does not believe in "Rule of Thumb" methods in scientific investigations.

Standard methods for laboratory practice may be outlined, and if followed intelligently are of unquestionable value.

We should all work together conscientiously to improve and obtain methods for the very best laboratory practice.

The question of a "Standard of Purity" is another matter. The German standard of 100 bacteria per c.c. is often quoted. The writer does not doubt for a moment the value of this and that it is applicable to the European conditions where it is used. The fact that it is sufficient for Germany is no argument that it is satisfactory for American conditions. We all know the conditions are different. We also know that the conditions vary in different parts of our own country.

The writer believes if we would only stop to give the time and attention the matter deserves and pay more careful attention to the analysis of our laboratory data, we could specify for each case very satisfactorily. This brings us to a point to consider laboratory practice.

The author seems to find little value in the usual chemical determinations. As a routine to determine the proper operations of filters, the writer agrees with him. On the other hand we must not leave the impression that this work should be entirely scrapped.

These same determinations are quite useful tools when intelligently used for specific purposes.

The author is right when he gives this impression that the average consumer pays more attention to the appearance than anything else. We must cater to the aesthetic side and no doubt the psychological effect of the presence of color, odor, and turbidity, all physical defects, has an influence on the health of the individual.

However, this is no argument that we should not also save the consumer from danger from water borne diseases as much as possible even in spite of himself.

This brings us to a point where we must consider our bacteriological tests. The writer agrees with the author that these are most important in the control of purification processes for sanitary purposes, also in determining the sanitary quality of any water.

It is true bacteriology is a new science and we must not try to fool ourselves that we have a more sensitive measure than we have. Yet we must not forget the rapid advances and lose sight of the fact that the shortcoming of today grows to a valuable asset tomorrow. Take the colon test for instance, which, as the author states, is but circumstantial evidence, yet such evidence is far better than no evidence. We are very much interested to know the possibil-

ities of infection. We certainly can avoid danger more intelligently if the possible ambush is pointed out to us.

The writer agrees that no degree of danger is admissible in our public supplies. He believes, however, that with the continued advance of bacteriological science we are going to be able to make a much closer and more definite diagnosis than we do at present on water.

He is not, however, too ready to assure plant operators that the laboratory expenses will be reduced thereby.

After all, in spite of the depressing trend of this paper, laboratory data has much value if it is intelligently obtained and intelligently analyzed. In order to do this, the man conducting the work should be thoroughly experienced in this class of work. If finances will not permit a resident of this type, then a consultant should be retained to review the data obtained in accord with his instructions. This is not extravagance, it is economy even for the smallest water works.

No matter how small the water works, a laboratory should not be considered an item of expense to be curtailed and cut off if possible, but rather as a matter of good finance and economy. The money spent in maintaining a laboratory is to a water supply what the premium is on an insurance policy. The fact that your neighbor has no insurance on his home and you have always had, and neither of you have met a loss, is no argument to cease your insurance or for him to continue without it. The fact that your water supply has existed without sanitary control and without serious results is not an argument that you don't need sanitary control.

Many will see another side to many of these points and we must read carefully and weigh each of the author's points on laboratory practice and standards of purity deliberately. It would be unfortunate for any of us by making hasty conclusions to fool ourselves into an erroneous conception of the true condition of affairs.

In enumerating the present limitations of these same conditions, let us not forget the rapid advances scientific investigation has made for us or the possibility of clearing up many of these hazy and unsatisfactory points, if we only direct our scientific investigation in a painstaking, patient, intelligent manner and above all on the true scientific principle.

Mr. C. E. A. Winslow (by letter): The writer is entirely in accord with the emphasis which Mr. Johnson lays on the study of

the color and turbidity and hardness and bacteria in the routine control of water supplies, and believes that a great deal of time is wasted in many laboratories in the determination of free and albuminoid ammonia, nitrites and nitrates. In many cities there is a surprising lack of correlation between water analysis and the control of the supply itself. If the results obtained in the laboratory are of value, except for purely statistical purposes, they should be communicated daily by telephone or otherwise to the engineer in charge of operating the plant, and, so far as they have a sanitary bearing, to the local health department as well. If they are not of sufficient importance to be so made of practical use they should be abandoned.

Mr. Theodore Horton (by letter): The writer is heartily in sympathy with most, if not all, of what the author has to say, but somewhat questions the expediency of sweeping aside so suddenly all of the old fashioned notions on the work which has been done in water analyses up to the present time. He is heartily in favor of a change, however, and is in accord with the author's idea that a great waste of time and energy has been expended in working out and recording many useless data.

The writer is particularly interested in the author's statement with reference to the value of tests for B. coli. He feels that such tests, in a great majority of cases, are the most valuable indicators we have, but that our ability correctly to interpret them is extremely doubtful. With reference to this point the writer has found that in the United States Canadian boundary waters, especially lake waters, while the bacterial counts are low, due in all probability to low temperature, the presence of B. coli in any dilution or number appears to be responded to by outbreaks of typhoid fever.

Particularly has this been noticeable along the St. Lawrence River, where the total number of bacteria is low and where we are barely able to detect B. coli in quantities of water as high as 10 cubic centimeters, but where typhoid seems to run rampant at times. The writer has endeavored to explain this apparent phenomenon in his recent report on his investigation of the pollution of the St. Lawrence River by attributing it to the short interval elapsing between the time that the pollution enters the river and the time the polluted water is consumed.

A point of vital importance seems to the writer to be the ratio of coli to the total number of bacteria which, as he views it, is, con-

sidering it as a percentage, very much higher in these swiftly flowing rivers connecting the Great Lakes which normally have comparatively low bacterial counts, and where opportunities for high dilution are afforded than in the case of other classes of slowly moving streams, not lake waters, wherein the total number of B. coli is much higher, and the percentage of coli is accordingly very much smaller.

The recent typhoid fever experience in Albany, during the flood of the Hudson River, described by the writer in the *Engineering News*, issue of May 15, 1913, and reprinted in the United States Public Health Bulletin of May 23, 1913, is a very pertinent case with reference to the discussion. The typhoid fever epidemic occurred during a flood of the river flow which corresponded in a measure to the ordinary flow condition of such rivers as the Niagara and St. Lawrence. The filter plant was inundated, and with only a comparatively momentary pollution of the water supply and with all of the warning it was possible to give the public, an epidemic appeared promptly on schedule time. The writer is of the opinion, therefore, that there is much in the point the author refers to with reference to the attenuation of the bacteria. If the organisms are fresh and virulent, a small number will perhaps cause as much infection as a considerably larger number might do if weakened by long exposure or other attenuating conditions.

Mr. Robert E. Milligan (by letter): Mr. Johnson's contribution on Pure and Wholesome Water brings formally before the Association a condition wellknown and understood by the filter companies, and which is perhaps expressed clearly in the guarantees forming part of contracts where filtered water is produced.

The word "pure" has always been held by the filter companies as a very inaccurate designation applied to water unless supported by certain standards that would bear the inspection of a court, and which could be construed not only in a practical sense, but in a legal sense as well.

Inasmuch as the object of filtration is to produce a satisfactory water, wholesome and suitable not only in its physical aspects, but in a sanitary and chemical sense as well, such guarantees have been most important and seem to express what is desirable in this respect. These can at least be said to have withstood the test of time, and the writer does not remember a single instance where these definitions as contained in the guarantees have been a source of injustice

to either the consumer or the purchaser. The commonly accepted guarantee of purity reads as follows:

"That the effluent (filtered water) shall be practically free from turbidity, color and matters in suspension, and when there are 3,000 or more bacteria per cubic centimeter in the raw applied water there shall be a removal in the filtered water equal to an average of 98 per cent; and when there are less than 3,300 bacteria per cubic centimeter in the raw applied water there shall not remain more than an average of 100 bacteria per cubic centimeter in the filtrate."

It will be noted that no reference is made to special bacteria such as B. coli, the filter man's assumption being that in the elimination of bacteria in a gross sense there directly follows an elimination to an even greater extent of the bacteria not common to water.

Leaving the question of water purity in a bacterial sense, there have always been made from time to time special guarantees for the elimination of detrimental substances, such as iron, and the guarantee that seems to have been followed in this regard is about as follows:

"If the raw water contains 2.0 parts per million there will be an average removal equal to 95 per cent; and if the raw water contains less than 2.0 parts per million there will not be more than 0.2 part per million in the filtrate."

There is no doubt that Mr. Johnson's position as to clarity of the water is sound. Considerable experience leads the writer to support his statements in this respect, that no water will be acceptable to the consumer that is not clear and bright independent of any other standard of purity.

The speaker is also of the opinion that chemical analyses, so far as they show nitrogen, are of little value in determining the character of a water in establishing a standard of pure, wholesome nature. Such factors, however, as alkalinity and hardness are of value, although with most of our American waters the boiler scale phase is rarely a subject under discussion in connection with questions of potability, and water softening is distinctly a field of its own which the writer does not understand to come within the scope of this valuable paper.

In the matter of chlorine it is quite true that the amount in filtered water has no significance except as indicating more or less a polluted condition in the original water. It does not show the difference between the animal and mineral pollution, which would

be all important so far as the sanitary quality of the water is concerned.

Mr. Langdon Pearse (by letter): Was pleased to note that Mr. Johnson has commented on a number of points which as yet seem to have escaped emphasis in such discussions. While the physical characteristics of a water are undoubtedly most important, and the most valuable information can be determined from the physical and bacterial examinations, the writer is not inclined to put chemical data entirely in the discard. This is particularly true on waters where the past history is of interest. The writer is inclined to favor the determinations, not only of physical and bacterial, but the chemical characteristics on isolated samples. On tests from water collected from a water supply where daily or weekly analyses are made, specific tests may be selected, of course, but the writer did not understand that this was Mr. Johnson's idea altogether.

The comment on the presence of industrial wastes in waters is of interest. A case that recently came to the writer's attention is at Whiting, Indiana, where a small residual waste from the Standard Oil Refineries gave the water supply a decided kerosene taste at times. In this particular instance the proximity of the intake and sewer outlet is very marked.

The writer has been much interested in Mr. Johnson's plea for the ignoring of the past history of a water, and placing reliance in its entirety upon a mechanical and chemical process of purification, and in particular the extreme case cited at the Stockyards filtration plant at Bubbly Creek in Chicago. The writer has already felt that while the presence of some organic matter in itself was not objectionable, the indications were that the past pollution might be objectionable. In the case mentioned by Mr. Johnson at Chicago, the filtration plant of commercial design of the rapid filter type was treating a water, largely sewage which ran from crude sewage with a flow of about 250 gallons per capita to a diluted sewage to a dilution of about 1 in 10 with Lake Michigan water. Such a condition is, of course, very unusual, and in this case success was only possible through the use of large amounts of chloride of lime. From hearsay evidence the writer has learned that this water had considerable taste, and would, therefore, have proved objectionable if offered as a source of supply for a municipality. He hardly thinks that Mr.

Johnson would recommend such a source of supply for a municipality, with any other available of less marked characteristics.

There is a point which should be emphasized in all such discussions, not only with reference to municipal supplies, but the handling of water on trains and in public places. The frequent sampling and tests in the laboratory are only a small part of the care that is necessary to avoid trouble. In a water as badly polluted as that of Bubbly Creek, if filtered and used for drinking water, constant watchful care is required to insure results, the human element is large, and the potentiality for trouble is therefore greater than if a water with a less odorous history were used.

In connection with the serving of water in public places from coolers, knowledge of the character of the water supply, not only from its source, but at the cooler is desirable, but testing on a large scale would entail very marked costs. It would, therefore, seem to be a matter of common sense to get at the protection of such waters from the standpoint of design of proper containers to minimize the liability to infection, because even water, originally very pure, can readily be contaminated in careless handling. The writer believes that attention should be paid to the design of containers and the development of proper methods of handling, even more than to making laboratory tests. In other words requirements should be laid down, not only for improving the method of handling water and ice and also for the construction of the containers, as well as for obtaining knowledge of the source of the waters and the ice. On a large municipal supply conditions are somewhat different, and effective policing in control of the watershed will do much. Laboratory tests are desirable as a control. The writer, however, believes that the need today is for more accurate knowledge of the relations of the laboratory methods to the actual results obtained, not only as expressed in the appearance of the water, but also in its effect upon the people and their health. Some of this Mr. Johnson has commented on.

In one paragraph Mr. Johnson has stated a condition which the writer thinks he would modify to make consistent with the balance of his paper. The text reads that a community should first purify their wastes to remove obnoxious conditions in a body of water used for supply and then require the purification of such waters. The writer has found that most sanitarians would reverse this order, and state that, as a general proposition, if a water supply is polluted, the most immediate and cheapest way is to purify the water and

then treat the sewage sufficiently to lessen the load upon the water filtration plant.

Mr. S. T. Powell (by letter): There is much food for thought in this valuable paper by Mr. Johnson, and many timely suggestions as to the importance and interpretations of water analysis data, which should receive very careful attention from members of this association who are directly or indirectly concerned in the subject.

Probably most of us who are in charge of water purification works will agree heartily with Mr. Johnson that careful and frequent determinations of the turbidity and suspended matter in water are necessary at all times, if the works are to be operated efficiently and economically. More and more attention has of late years been paid to this phase of water analysis, but there is still much room for improvement of the methods in vogue, as well as more systematic study of these features. This applies not only to the operation of filtration plants but to the sterilization with chlorine compounds, ozone, ultra violet rays, or any other methods yet devised.

A point of no less importance in the paper before us is the reference made to the interpretation of the analytical data. It seems unreasonable to believe that with our present knowledge of water analysis, that any trained chemist or sanitary engineer would draw his conclusion as to the potability of a water according to any set of specified standards. Yet, from time to time, apparently such procedure is followed. This, in many instances, is due to habit on the part of the analyst, of interpreting chemical data other than water, according to certain specified standards; and secondly, because of insufficient knowledge of all the factors, other than the chemical and bacterial data, that have a direct bearing upon the interpretation of the results.

Following are the characteristic requisites of good drinking water that are printed upon the reports of all water analyses sent from the laboratory of a certain Board of Health:

> Good drinking water should be clear and colorless, without odor and neutral in reaction.
>
> 1. The "Total Residue" should not exceed 500 parts per million.
> 2. The "Ignited Residue" may constitute the total residue.
> 3. The smaller the amount of "Volatile Residue" the better.

4. The amount of "Chlorine" should not exceed 6.00 parts per million.

5. The amount of "Nitrogen as Free Ammonia" should not exceed .05 parts per million.

6. The amount of "Nitrogen as Albuminoid Ammonia" should not exceed .15 parts per million.

7. The amount of "Nitrogen as Nitrates" should not exceed 5.00 parts per million.

8. There should be no "Nitrites" present, as these indicate active decomposition of organic matter.

9. The amount of "Earthy Bases" should not exceed 200.00 parts per million.

10. The amount of "Sulphates" should not exceed 100.00 parts per million.

As to the bacteriological aspect of the water examined, there is printed on the reverse side of the report of the bacteriologist an "Explanation of the Findings," that is given herewith:

Explanation of Findings

When we report that the colon bacillus is present in water, we simply mean that intestinal material is present in drinking water. This does not necessarily mean that the intestinal contamination is from human sources, since the colon or intestinal bacillus is always present in the intestinal contents of warmblooded animals. The contamination of the drinking water, therefore, may arise from contamination of the underground water system, by means of a deep cesspit, or by means of surface contamination from improperly constructed surface privies. These are the two most frequent sources of pollution from human habitations. On the other hand, barnyards, leaky or overflowing manure pits, stables, chicken yards, cow stables, and even manured fields and cow pastures may be the sources from which the intestinal bacillus gains its entrance into the water supply.

The presence of the intestinal or colon bacillus in drinking water does mean, however, that the route for infection is open, and if the intestinal contents from any of the intestinal diseases, such as typhoid fever, paratyphoid infection, diarrhea, dysentery, and food or ptomaine poisoning are introduced into any of these sources of pollution, they are apt to get into the drinking water and produce such diseases in healthy persons.

If we report the presumptive test as positive, and the water as suspicious, it means for practical purposes that the intestinal or colon bacillus is present in the water, since the water produced the fermentation of the sugars used for the detection of intestinal pollution. This report, however, means that we have been unable to isolate the organism in pure culture from the water. The test should act as a warning, however, and the water may be regarded as under suspicion, until further tests have shown that the water produces no gas formation in our test cultures, and the presumptive test is therefore negative. Occasionally we condemn the water for a very high bacterial count, although we have not found any evidence of intestinal pollution. It will be found usually in such cases that the water has not been properly refrigerated, and the bacteria have simply increased in the sample after its collection.

The Number of Bacteria Present in Drinking Water.

It is very difficult to establish an arbitrary standard for the exact number of bacteria which would render a water pure or polluted, but it may be stated that pure water from a deep source, such as unpolluted artesian wells, driven wells, deep wells and springs, will contain from 100 to 300 bacteria per cubic centimeter. On the other hand, surface waters may contain from 500 to 1000 bacteria, and still not show any evidence of intestinal pollution. The number of bacteria in drinking water is so variable, however, that these figures may vary widely.

It is doubtful if the able and well trained men in charge of the departments really draw their conclusions solely from the analytical data and base their findings upon the standard printed upon the report blanks. If such, however, is the case, their methods, to say the least, are antiquated.

If the standards are not used, then it is indeed inconsistent to present them to the layman as a set of rules for the interpretation of analytical data, which the chemist has not followed.

To the writer's mind it seems unnecessary to attempt any such explanation as to the interpretation of the results of the analysis of water. The reason for this belief is that so many factors other than the analytical data must of necessity enter into the interpreta-

tion, that standards of any character must be misleading and incoherent.

It appears very much like a physician laying before a patient the symptoms of his disease and having him diagnose his ailment.

Dr. Gilbert Fowler (by letter): Pure water is obtained in the laboratory by distillation into a clean receiver, and in nature when water is distilled, condensed as rain and collected in a clean gathering ground. This latter is clearly the ideal method for obtaining water, and any process short of this should be of necessity and not of choice. Even rain, it may be remarked, is subject to pollution when rain clouds pass over smoky cities. For this, and other reasons, gathering grounds should be as far removed from towns as possible.

Methods which rely on the artificial purification or treatment of water originally impure are always subject to the possibility of accident or carelessness, although the danger may be greatly reduced, as Dr. Houston has shown, by adequate storage. The fact still remains, however, that water originally polluted by sewage is water which has passed through the bodies of human beings, and thus is essentially different from water which has been distilled by the sun.

Few processes of purification reduce impurity by 100 per cent, and in any event the products of oxidation still remain. While all this may be admitted it may still be contended that artificially treated waters have not been shown to be dangerous to health. This is probably quite true, but in the last analysis it may be found that this, like other kindred questions, is one of ethics and aesthetics, even more than of hygiene in the restricted sense.

It is difficult e. g. to obtain statistical proof of the ill-effects of smoke on health, yet the fact of the adaptability of the human organisms can surely be no excuse for breathing a filthy atmosphere. The writer would therefore strongly depreciate any tendency to laxity in the provision of a water supply beyond reproach. Artificial processes of treating water originally impure, while of course necessary and inevitable in special cases, should be looked upon as abnormal.

Other points raised in Mr. Johnson's paper are subordinate to the above contentions and the writer would merely add that chemical analysis is useful, not for the purpose of obtaining a rigid standard, but of following the changes in the composition of water during filtration, or other processes of purification.

Dr. Ad. Kemna (by letter): The speaker has read this paper with great interest and pleasure, one reason being that in December last he dealt with about the same subject in a paper before the Institute of Water Engineers, London. We lay great stress on "reasonable" requirements of water purity. The speaker claims "common sense" even in questions of water supply, and is in complete agreement with Mr. Johnson. Things are better in the States than elsewhere because generally the American water engineer has a thorough knowledge of chemistry and bacteriology, and so is able to appreciate the real value of the data supplied by these auxiliary sciences.

Mr. George A. Johnson: The author is much gratified by the discussion submitted on his paper which was written in an intentionally more or less interrogative vein, seeking only to set forth the facts and fallacies as they arranged themselves in his mind, and trusting to the discussions for corroboration. He particularly desired not to appear dogmatic, not iconoclastic, but, having been in the earlier years of his professional life essentially a laboratory man, whose business it so often is not to interpret results but merely to obtain them, and later in the broader field being obliged to interpret such results, and, if possible, obtain actual value from them, he felt constrained to set forth his views, based upon some 18 years of actual experience. The discussions submitted have been so complete, and in the main so thoroughly in accord with the author's own opinions, that in closing he will refer only to a few points.

Mr. Hering's remarks with reference to furnishing water of low temperature to the consumer, this end to be accomplished by underground storage, are interesting. The author does not feel that such underground storage will prevent the growth of pathogenic germs any more than storage in open exposed reservoirs, inasmuch as he does not believe that pathogenic germs multiply in such environments, but rather die off with considerable rapidity. The idea of keeping cool the water as supplied to the consumer, wherever practicable, has always appealed forcibly to the author. Indeed, in a certain eastern city where he is serving on an additional water supply problem, many of the inhabitants interested, having become accustomed to the cool spring water they have been receiving for many years, objected strenuously to the idea of the addi-

tional supply coming from a nearby river. In short, it was not so much the quantity and purity of the additional supply that worried them, as the fact that it would be warmer than the old supply and necessitate the purchase of ice for cooling purposes.

Mr. Fuller calls attention to the fact that data on tastes and odors are not ordinarily obtained with sufficient care in the case of many reservoir waters. This is undoubtedly true, and may also well apply to some river supplies. Mr. Fuller believes that more careful study of these features "would be preferable to making many albuminoid ammonia tests on some waters," and again the author agrees with him, only he is inclined to the belief that he would not make *any* albuminoid ammonia tests on *any* water, at least as a regular procedure.

The author is glad that Mr. Fuller called attention to the importance of dissolved oxygen tests on reservoir waters which stratify, and where objectionable tastes and odors are liable to be produced through stagnation. The author overlooked this point in preparing his paper, but gratefully acknowledges its importance as stated by Mr. Fuller.

As to iron, Mr. Fuller sets a somewhat lower permissible limit than the author, but it is true, as Mr. Fuller says, that in some cases, and dependent upon the composition of the water, the amount which causes a precipitate of iron to appear is sometimes as low as 0.5 or even 0.25 part per million.

Mr. Ellms seems to consider the author unduly pessimistic, and states that sanitarians are constantly distinguishing between pure and impure waters despite the varied and complex character of the data set before them. The author never for a moment meant to convey the sweeping idea that a chemical analysis had never been correctly interpreted, but rather, in the face of the analytical data usually furnished, it is quite as likely that the interpretation may be correct now, and miles out of the way again. Not a few innocent waters have been unwarrantably condemned on chlorine and nitrogen data, and there are cases where pure spring waters, due to the carelessness of birds when in transit over them, have suffered a similar laboratory fate. The author continues of the opinion that nitrogen data are particularly lacking in definiteness of information with respect to the quality of a water supply.

Mr. Ellms is obviously concerned over the prospect of "dis-

carding the only available method for obtaining information," but the author contends that unless such data furnish definite knowledge they should be discarded, for being indefinite they are capable of pernicious misinterpretation.

Mr. Baton's acceptance under European conditions of the German standard of 100 bacteria per cubic centimeter, and his hesitancy to accept it for American conditions, leads the author to wonder what standard for the total number of bacteria Mr. Baton would set. Presumably he would set a higher standard where the water before purification is badly polluted, and a lower standard where the raw water is relatively free from pollution, the idea being that the more impure the water originally the greater the probability of there being a greater proportion of pathogenic bacteria in the filtered product. There undoubtedly is something in this idea, but the hypochlorite treatment has largely solved the problem of the residual pathogenic bacteria.

The author is inclined to doubt Mr. Baton's statement that the paper has a "depressing trend." He was laboring under the fond belief that, if anything, it was in some measure progressive. It is easy to understand, however, that no one is wholly cheered by the thought that so many hours of his life may have been spent in unproductive labor, yet the author has placed himself in precisely this same category, and still is far from feeling sad over the prospect that he will waste no more time in the same Jack o' Lantern line of endeavor.

Mr. Horton questions the expediency of sweeping aside so suddenly the old fashioned notions, but thinks that there has been a great deal of time and energy wasted in working out and recording many useless data. The author desires nothing less than casting aside *all* the old fashioned notions, but those which lead us nowhere clearly should be discarded without delay.

Mr. Horton's references to the value of the colon test, and his experience with it along the St. Lawrence River and in the Great Lake waters, are most interesting and instructive. In the cases he mentioned, where the presence of B. coli in any dilution or numbers, however low, appeared to be responded to by outbreaks of typhoid fever, it seems quite probable that the explanation for this lies in the fact that the pollution was specific, and reached the ultimate consumers swiftly, as pointed out by Mr. Horton. His point

that the ratio of coli to the total number of bacteria seems most important as indicating actual danger seems well taken, but how lacking in immediate, and in this case real, value is this test where days must elapse before such results can be obtained, for, when obtained, the danger may be past. Here is the weakest spot in the bacteriological armor as referred to water analysis. The importance of direct methods of bacterial analysis is well appreciated, but, as yet, such methods have been but very incompletely developed.

Mr. Milligan's references to guarantees of efficiency, which commonly form a part of contracts between filter companies and the purchasers of filters, show the one definite manner of establishing a standard which is useful in cases of legal controversy. So far as they go, these guarantees are valuable, and are without doubt one of the best, if not the best, of the so called standards of purity available to us.

Mr. Pearse also seems to think that it is the writer's intent to put chemical analytical data entirely in the discard. A careful review of the paper will show that this is an erroneous view, and inasmuch as this phase has already been commented upon, further elucidation seems unnecessary.

Mr. Pearse appears inclined to favor the chemical analysis of isolated samples of water. To the writer's mind such data are of almost no value at all. They are not likely to be quite so valueless as a single bacterial analysis, but certainly, if only a series of chemical analyses is of value in proving the physical characteristics of a water, and giving a definite line on its hardness, chlorine, iron and dissolved oxygen content, of what use are the data secured from a single sample, except insofar as they may indicate certain idiosyncracies of a water, or its peculiar characteristics on a particular day? Every constituent will vary tremendously in amount from day to day and month to month, in some cases to the extent of hundreds of per cent.

The author does not quite comprehend Mr. Pearse's attitude in stating that he "is interested in Mr. Johnson's *plea* for the ignoring of the past history of a water." It is the immediate present, as regards the character of a water supply, that the author is particularly interested in. In citing the case of Bubbly Creek and the Chicago stockyards filter plant the author merely desired to again place on record what certain other sanitarians believed with regard

to the non-poisonous features of an initially foully polluted water afterwards purified by rapid sand filters. The author did not recommend this supply, even after filtering, for drinking purposes, for the aim was only to make this water fit for stock watering and steam-raising uses. Nevertheless, at the time when this matters was under the immediate supervision of the author, he believed, and still believes, that the product of the filter plant was safer for primary uses than the city supply. It is, however, unnecessary to state that a supply with less marked characteristics would preferably be recommended by the author as a source of public water supply.

Mr. Pearse is right in the assumption that the author would purify water, and consider the satisfactory disposal of sewage, in the order named. The author was considering both problems broadly, and very likely left the impression on Mr. Pearse's mind that he was beginning at the wrong end.

The author has been much interested in Mr. Powell's discussion, feeling that in it there is much food for thought.

Doctor Fowler's viewpoint that the ideal method of obtaining a water supply is to get it from an unpolluted source and keep it pure as delivered to the consumer is, to the mind of the author, an eminently proper one, and one from which few people would care to dissent. But how many large cities are situated so fortunately that such a supply can be obtained within limits of reasonable cost? It is indeed true that the protection of water supplies through purchase of the watershed or protection by legal enactments is more widely practiced in Great Britain than in any other country. Among notable examples in this regard are Manchester, Liverpool, Edinburgh, and Glasgow. In this country the most notable example of a protected water supply is that of Boston, Massachusetts. Los Angeles, California, is completing a new system whereby water will be piped from a distance of some two hundred and fifty miles. On the other hand practically all the other large cities, in addition to such protection as may be afforded by sanitary patrol, are in some manner purifying their supplies before delivery to the consumers. New York City, after going some 100 miles to the Catskill Mountains for an additional supply has made provision for filtration of this water. Along this general line of thought much instructive information may be obtained by reference to the Trans-

actions of the American Society of Civil Engineers, Vol. LIX, December, 1907, p. 367, *et seq.*

Doctor Kemna's claim that the exercise of common sense is necessary even in questions of water supply strikes a particularly responsive chord in the author's mind. It is this very idea that the author was striving to impress upon the minds of the readers of his paper.

MICROÖRGANISM TROUBLES IN THE OPERATION OF MECHANICAL FILTERS

By Frederick H. Stover

The chief functions of water filters being the removal of bacteria and suspended matter from the supply, the natural inference would be that the operation of the plant would be easiest at the times when these substances are present in least amount. Many filter superintendents, however, find that such is not always the case, and that warm weather and clear water bring troubles peculiarly their own.

The usual symptoms of these troubles are marked shortening in the length of the filter runs, and the prevalence about the filter beds of a pronounced odor, varying from "grassy" to "fishy" in nature, and often of considerable intensity. Microscopical examination of the water at such times usually reveals the presence of numerous minute forms of the type generally classified by waterworks men as "microörganisms," and which in the waters of the Ohio River are principally diatoms, with a few algae and miscellaneous forms present.

It should be understood that the bacteria are not included in this class but that they consist of organisms ranging in size from slightly above the bacteria up to forms that are easily visible to the naked eye.

These organisms are usually accompanied by considerable amounts of very fine flocculent, amorphous matter, the exact nature and origin of which is uncertain, but which in part at least is probably the result of bacterial action upon various organic substances present in the water. Since it is often present in increased amounts when these microörganisms abound, it is extremely likely that part of it is also due to the activities of these forms.

The river water at such times usually has a turbidity of less than 30 parts per million, and frequently as low as 5 to 10 parts per million, while the bacterial count will vary from 300 to 3000 at the lower turbidities.

These periods of clear water are coincident with the periods of least rainfall, and the river falls to its lowest stages during these

times. These conditions of clear, warm and shallow water, abundant sunlight, and sluggish current afford these microörganisms the most favorable conditions for development and their numbers increase rapidly at such times.

At Louisville the water is pumped from the river into two reservoirs having a total capacity of 100,000,000 gallons, and which allow of about four days natural sedimentation before the coagulant is added. As these are simply open basins the organisms, in some cases, increase while passing through them, but the greater depth of water (20 feet) renders the conditions somewhat less favorable, than would be encountered in the shallower parts of the river.

Of the varieties of microörganisms found in the water about 75 per cent are diatoms, the remainder belonging to the algae and miscellaneous groups. The forms of diatoms most commonly present are Asterionella, Synedra and Melosira.

As stated above it is only with waters of low turbidity that these troubles occur, and then in marked degree apparently only when the number of organisms present exceeds 200 to 300 per cubic centimetre.

At these times the turbidity which is present consists of extremely finely divided particles, and it is the opinion of the author that each of these factors, i. e., Microörganisms, amorphous matter, and fine turbidity, does its share in the shortening of the filter runs.

Thus it will follow that when all these are found together the maximum effect will be produced, while any one or two of the factors will by themselves diminish the length of the runs, although not in so marked a degree as when all of them occur at the same time. The evidence in support of this may be given briefly as follows:

Low turbidities, averaging about 30 parts per million, occurred during the latter 10 days of September, 1912, at which time the water contained very few organisms and very little amorphous matter. During the first 20 days of this month the filter runs averaged 40 hours between washings, while for the latter third of the month, when using this water of less turbidity, they dropped to an average of 25 hours, a decrease of 38 per cent.

With these very low turbidities it becomes increasingly difficult to secure a "floc" of proper size and consistency, and as a result the suspended matter is able to penetrate more deeply into the sand layer than under normal conditions. In the absence of any considerable number of organisms or amorphous matter this shortening of the filter runs was attributed to the fine turbidity alone.

Early in May, 1913, a gradual shortening of the filter runs was observed and microscopical examination of the water showed from 20 to 30 organisms only present per cubic centimetre. Amorphous matter was, however, present in large amount and continued so for several days, the length of the filter runs decreasing from 30 to 11 hours in a period of 9 days, although the number of organisms present during this time never exceeded 200 per cubic centimetre, and remained during most of the period considerably below this figure. (See Plate IV, May 1–9.)

An instance of the combined effects of all three factors may be observed on the same chart between the dates of May 9–24, and similar conditions have prevailed at the time, showing the shortest filter runs on the other charts.

It is not claimed that the fluctuations in the length of the filter runs are definitely proportional to the amounts of these substances present, but that there seems, from the limited number of observations made, to be a general relation between these factors, and the length of runs attainable with the filters.

The exact influence of the amorphous matter is less certain than that of the other factors, and as it was not until more recently that the writer attempted to make a definite record of the amounts of it present, no figures of it will be given in this paper.

The only present method of estimating amorphous matter is in so-called Standard-Units, which take no account of the volume of the substance; hence there are obvious limitations upon the accuracy of any deductions based upon figures recorded in such units.

GENERAL EFFECTS UPON FILTERS

The first sign of approaching trouble is usually noticed after using for several days a water having a turbidity of about 30 parts per million or less, when a progressive decrease in the length of the runs commences. Filters which have been making 30-hour runs without reaching over 4 or 5 feet loss of head will drop to 25 or 20 hours inside of a couple of days and will reach a maximum loss of head (8 feet) in this time. In other cases successive runs will show a decrease of 25 to 50 per cent, especially as the runs drop below 25 hours, when the decrease has sometimes been so rapid that at the end of a few days the best runs would average only 2 to 3 hours in length. (Plate I, August 16.)

At such times the surface of the sand in the filters seems to become abnormally hard and compact in a short time, and when broken

up the sand grains show a slight tendency to stick together, which cannot be wholly corrected even by thorough washing.

Microscopic examination of the sand when in this condition usually reveals the presence of numerous diatoms and other organisms, apparently cemented together in a matrix of amorphous matter and fine turbidity.

It is the opinion of the writer that these living organisms in some way accelarate the formation and retention of this gelatinous film on the sand grains. In support of this may be mentioned the following:

During the period from May 19 to June 14, 1911 (Plate II), the number of microörganisms in practically all the samples examined was about 600 per cubic centimetre, the variations, except in one instance, from this number being so slight that it may be said to have remained practically constant. Yet during this period the length of the filter runs steadily decreased, until application of copper sulphate was made on May 26, following which there was a general increase in the length of the runs for a period of 6 days.

The only observable difference in the water coming to the filters during this period was that it contained dead instead of living organisms. The amount of turbidity and amorphous matter and the number of organisms were practically unchanged, the shortening of the runs having been apparently due to the cumulative effects of a constant number of organisms.

A similar increase in the length of the runs has also been observed when the organisms in the water died, apparently from some natural causes. The rise in the curve between the dates June 6–8 on the same chart (Plate II) is attributed to this, as at this time the effect of the copper sulphate treatment of May 26 was at an end and the higher turbidity of June 10–11 had not yet arrived.

Plates III and IV represent periods during which enough counts of the numbers of microörganisms present were made to enable a curve showing their variations to be plotted with reasonable accuracy, and it will be observed that during the times that the turbidity curve remains approximately constant the increases and decreases in the length of the filter runs follow quite closely the variations in the number of microörganisms present.

INCREASED USE OF WASH WATER

The decreases in the length of the filter runs of course cause correspondingly large increases in the amounts of wash water used.

During the year 1912 the average amount of wash water used at Louisville was 2.05 per cent, the lowest average for any one month being 1.44 per cent. During the periods of shortened filter runs, however, the amounts will vary from 6 to 10.7 per cent.

METHODS OF TREATMENT

The methods of treatment tested have been of three kinds:

1. Killing by chemicals.
2. Attempted removal by increased coagulation.
3. Obtaining a different character of water, as in bypassing the sedimentation basins and drawing direct from the river.

These three methods will be considered in the order given.

1. KILLING BY CHEMICALS

The use of hypochlorite of lime for this purpose had been considered early in 1911, but before an opportunity offered for a trial of it some results of its use in this way were published by Mr. Ellms of Cincinnati, in the spring of 1911. His experiments were attended by some success, but the results were not all that could be desired. One of his conclusions was that the nearer the hypo was applied to the filter beds, the better the results in increasing the length of the filter runs, and that hypo applied directly to the filter beds gave the best results of all.

Not being equipped with devices for applying hypo accurately as a continuously fed solution, it was decided to apply it as a powder to one of the filter beds. This was done by draining off the filter until about 3 inches of water remained on it, and scattering the powder uniformly over the surface, after which the bed was allowed to stand for a period of 24 hours. It was then washed and put into service.

No improvement in the length of the runs followed this treatment, and the bacterial efficiency of the bed for several days following was much below normal. The amount of hypo used was 12 pounds on a filter 30 feet x 72 feet in size. No further experiments were made with the hypo.

USE OF COPPER SULPHATE

With the copper sulphate applications markedly favorable results have been secured in all but one instance, and even in this case the results cannot be said to have been negative, as the runs were kept at 6 hours and above under conditions when much lower ones

might have been expected, and probably would have occurred had not the copper been used. The minimum length of runs reached at this time was 5 hours, which occurred 9 days after this dosing.

Plates I and II show the results of other treatments with copper sulphate, which were attended with much more marked success. It will be observed that within 24 hours after the application of the copper, there was in each instance a noticeable increase in the length of the filter runs and that these lengthened runs continued for periods varying from 8 to 19 days in length.

The copper was applied in the second sedimentation basin and in the coagulant basin, by dragging bags of it from a boat. It is probable, however, that equally good results could be obtained by applying it as a solution, in a manner similar to that by which alum or hypo is applied.

In plants not provided with sedimentation basins, but which run the incoming water direct to coagulant basins, at least 12 hours should be allowed between the application of the copper and the filtering of the water, and a slightly longer period would be desirable if possible.

Given in tabular form the cost and amounts of the chemical used in the various treatments were as follows:

DATE	CUSO[4] USED POUNDS	PTS. PER MIL.	EFFECTS LASTED (DAYS)	TOTAL COST	COST PER MIL. GALS. OF WATER		VALUE WASH WATER SAVED.[1]
					Dosed	Filtered.	
Aug. 20, '10	650	1.3	19	$31.20	50¢	6.5¢	
May 27, '11	735	1.3	10	36.00	52¢	10.4¢	$149.76
Jun. 15, '11	1000	1.7	9	49.00	70¢	21.7¢	228.50
Jun. 10, '12	625	1.2	9	30.60	49¢	13.2¢	

Some of these doses may seem rather large to those who have used this means for eliminating algae from a supply, but it has been the experience of the writer that the diatoms offer rather more resistance to the action of copper than do the algae.

It should also be borne in mind that from the reservoir to which this copper was applied about half the contents are drawn off daily. Theoretically there would be an entirely new supply of water in the reservoir every two days. Practically, on account of cross currents and other influences, it takes much longer than this, and the doses were effective over varying periods of from 8 to 19 days.

[1] At $30 per million gallons.

Usually the length of the filter runs would begin to increase in from 12 to 24 hours after the application of the copper, and the beneficial effects lasted for the periods mentioned above. Hence in figuring the cost per million gallons filtered the cost was apportioned over the amount of water filtered during the period of increased runs following the application of the chemical.

A careful examination of the water from the basins both as it flowed to the filters after coagulation, and again after filtration failed to reveal the presence of even a trace of copper.

There were numerous fish in the reservoir including bass, sunfish, cat-fish, gars, carp, etc., but except in the case of a few very small and apparently newly hatched ones, practically none were killed. During and for a few hours subsequent to the application of the copper a few large ones were observed to come to the surface for a short time, acting slightly dazed, but it was apparently a temporary effect only.

The only drawback to the application of the copper is that a large increase of bacteria has been observed to follow its use, but this may be in some measure due to local conditions, and need not necessarily be met with in other waters. The writer has seen water in other localities treated in this way and no such increase follow, but in other instances similar increases have been noted.

The explanation of this bacterial increase is probably that the killing of the microörganisms and possibly some of the less resistant bacteria leaves some of the hardier forms in the midst of an abundant food supply, and freed for the moment from any antagonistic effects of other forms, hence a rapid increase follows for a short period.

No B. coli were detected during this time, however, and it was found that the application of .25 parts per million of available chlorine was sufficient to eliminate this increase, so that in plants provided with a hyposterilization plant this increase can be readily taken care of if it occurs.

2. REMOVAL OF ORGANISMS BY INCREASED DOSES OF COAGULANT

The removal of the microörganisms by increasing the dose of coagulant beyond that necessary for bacterial efficiency was tried but did not give results of a promising nature. Doubling the normal dose of coagulant increased the removal of the organisms by only 10 per cent, and had very little effect on the runs.

3. RUNNING RIVER WATER DIRECT TO COAGULANT BASINS

This expedient was tried in two instances, and in both cases gave encouraging results, although in each case an increase in turbidity followed within a few days and thus left no opportunity to see how long this improvement would have lasted.

In addition to the regular determinations of microörganisms and amorphous matter, the writer has found of considerable value the determination of the actual time of filtration of a given volume of the water under investigation.

This has been done by using what may be termed a miniature filter. In order to expedite matters the Sedgwick-Rafter filter which is commonly employed to concentrate microörganisms before counting was used, and thus all the determinations were made with one sample.

In the river sample of June 21, 1912 (Plate III), it was observed that the time of filtration of 500 cubic centimetres through the Sedgwick-Rafter filter was only one hour as compared to about three hours for the water which was coming from the sedimentation basins. The river sample contained about the same number of organisms but much less amorphous matter than the sedimented sample.

The sedimentation basins were, therefore, bypassed and the river water run direct to the coagulant basins. An immediate increase in the length of the runs followed the increase, being from 5 to 9 hours in the following three days. A rise in turbidity occurring at this time put the runs back to normal. A similar though not as marked an increase in the length of the filter runs was secured in the same manner in May, 1913 (Plate IV).

The samples on which the time of filtration was noted were simply poured onto the small filter just as for an ordinary examination for microörganisms, care being taken to use exactly the same amounts of sand and water in each instance. When the turbidity of the water much exceeds 50 parts per million these small filters clog rapidly, and this determination becomes of no value.

This test has one advantage, however, in that it can be made by a person not familiar with microörganism work and it does not require the use of a microscope.

The writer does not wish to claim on the basis of the few determinations made that this time observation will infallibly be of value

but it has proved so in the cases cited, and it is hoped that it may prove useful if tried on other waters.

In closing the writer wishes to acknowledge his thanks to Mr. W. H. Lovejoy, Supt. of Filtration, for the use of the various records of his office. The dosing of the reservoirs was done under his direction, while most of the laboratory work was carried out by the author.

SUMMARY

In conclusion the following points may be mentioned:

1. The water of the Ohio River when of a turbidity below 30 parts per million almost invariably causes decreases in the length of the filter runs.

2. If such turbidities are accompanied by microörganisms and much amorphous matter, still greater decreases follow.

3. Filter runs may be greatly increased by the judicious use of copper sulphate, although after growths of bacteria sometimes follow its application and must be guarded against.

4. Small doses of hypochlorite of lime do not affect these microorganisms in such a way as to increase the length of the filter runs.

5. The determination of the time of filtration of samples of water through small laboratory filters, will in some instances enable the operator to select the water from that point of his system which will give the longest filter runs.

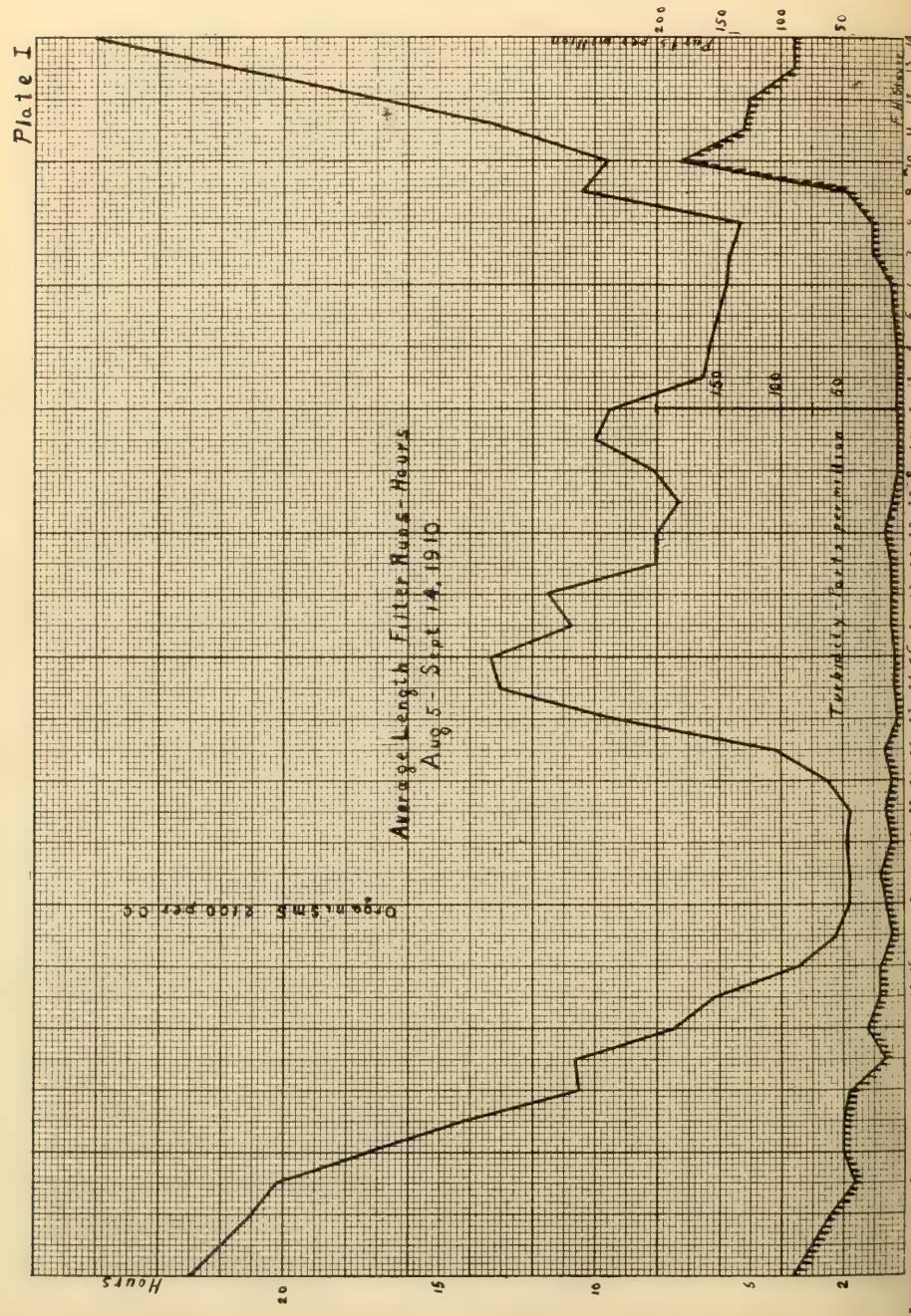


Plate I
Average Length Filter Runs-Hours
Aug 5 - Sept 14, 1910
Organisms Per cc
Hours
Turbidity - Parts per Million
↑ Cu SO4 Applied

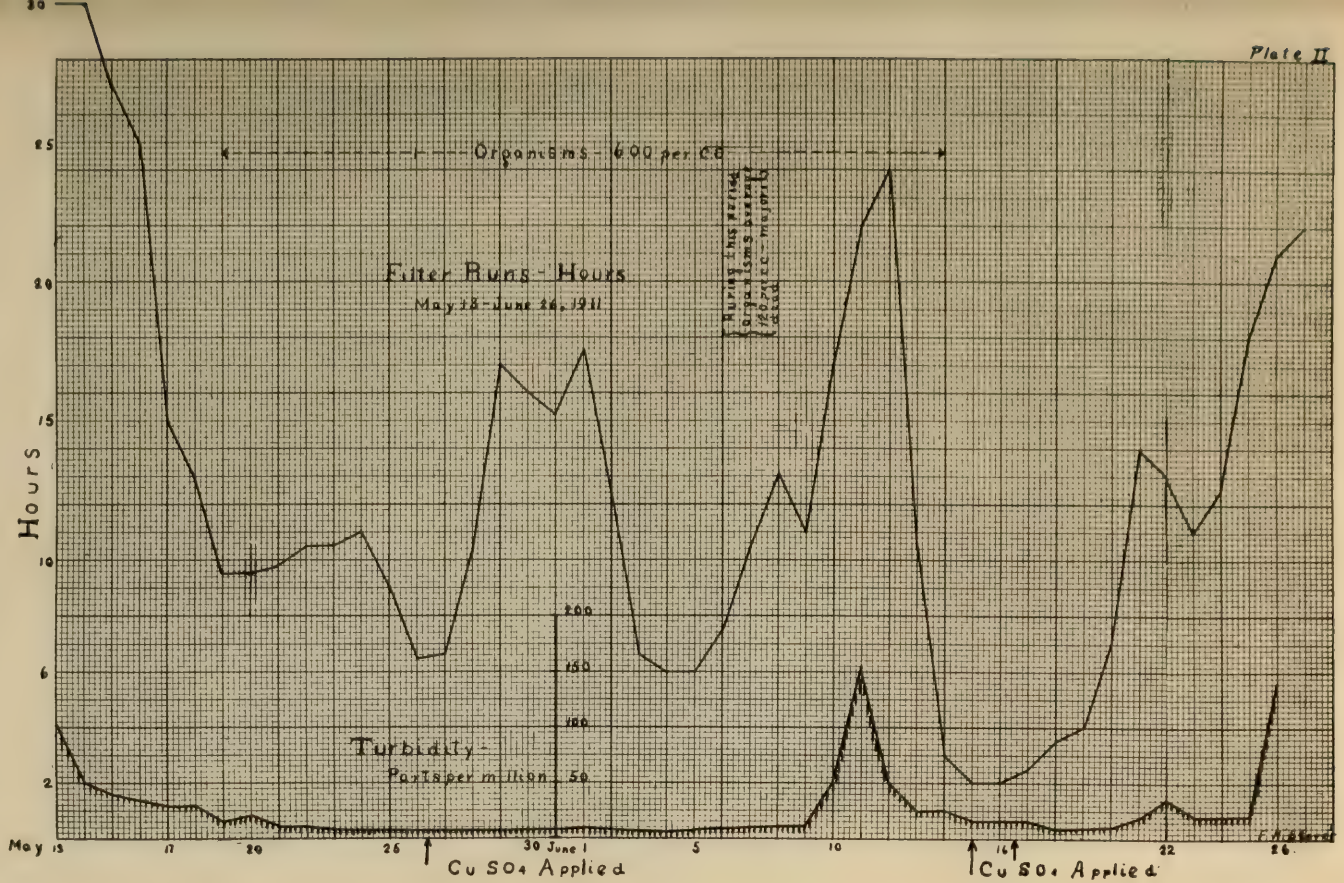


Plate II
Organisms - 600 per cc
Filter Runs - Hours
May 18 - June 26, 1911
During this period organisms passed 1 to 200 per cc - majority 50 to 100
Hours
Turbidity - Parts per million
Cu SO4 Applied
Cu SO4 Applied
May
30 June 1

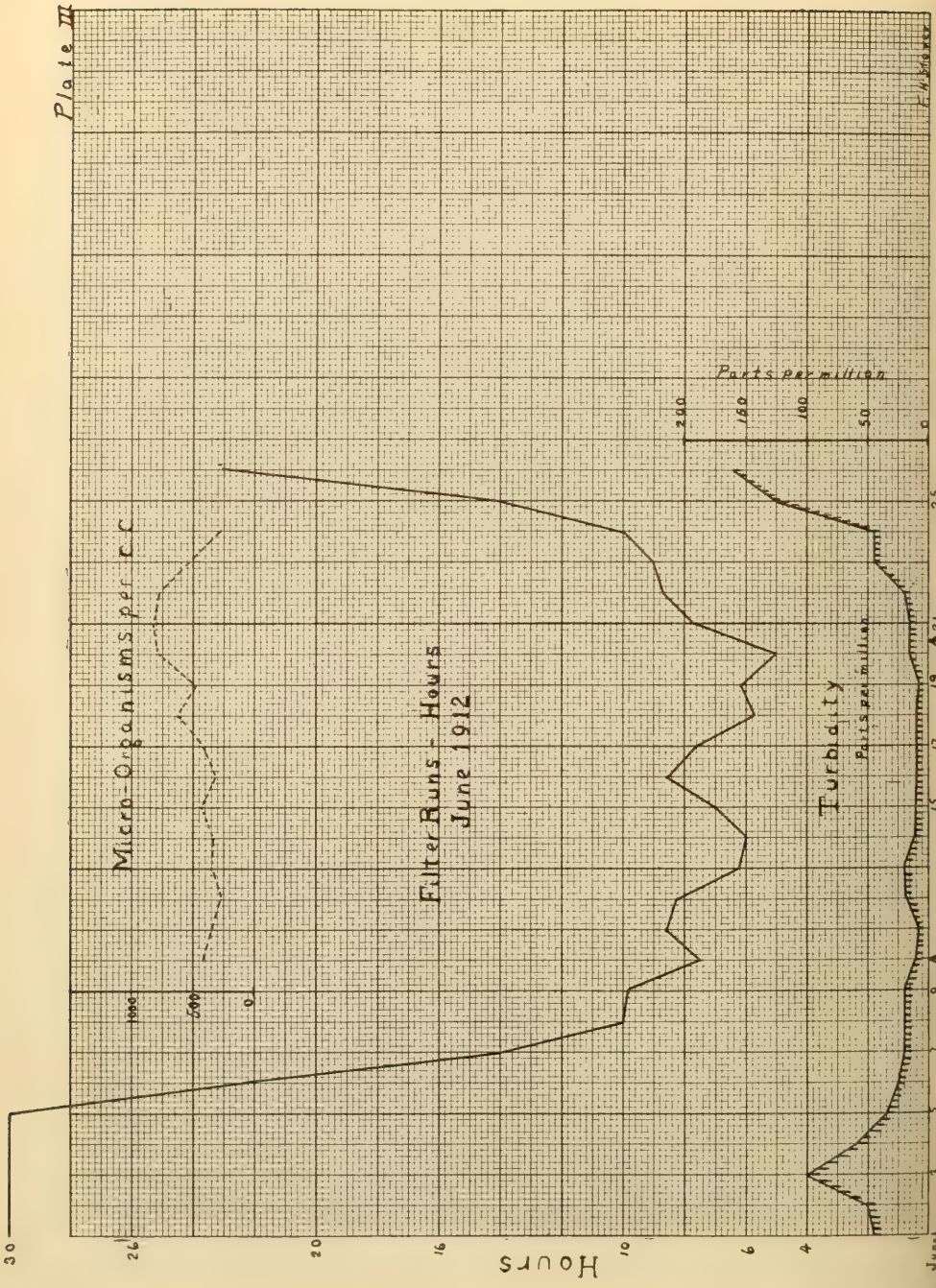
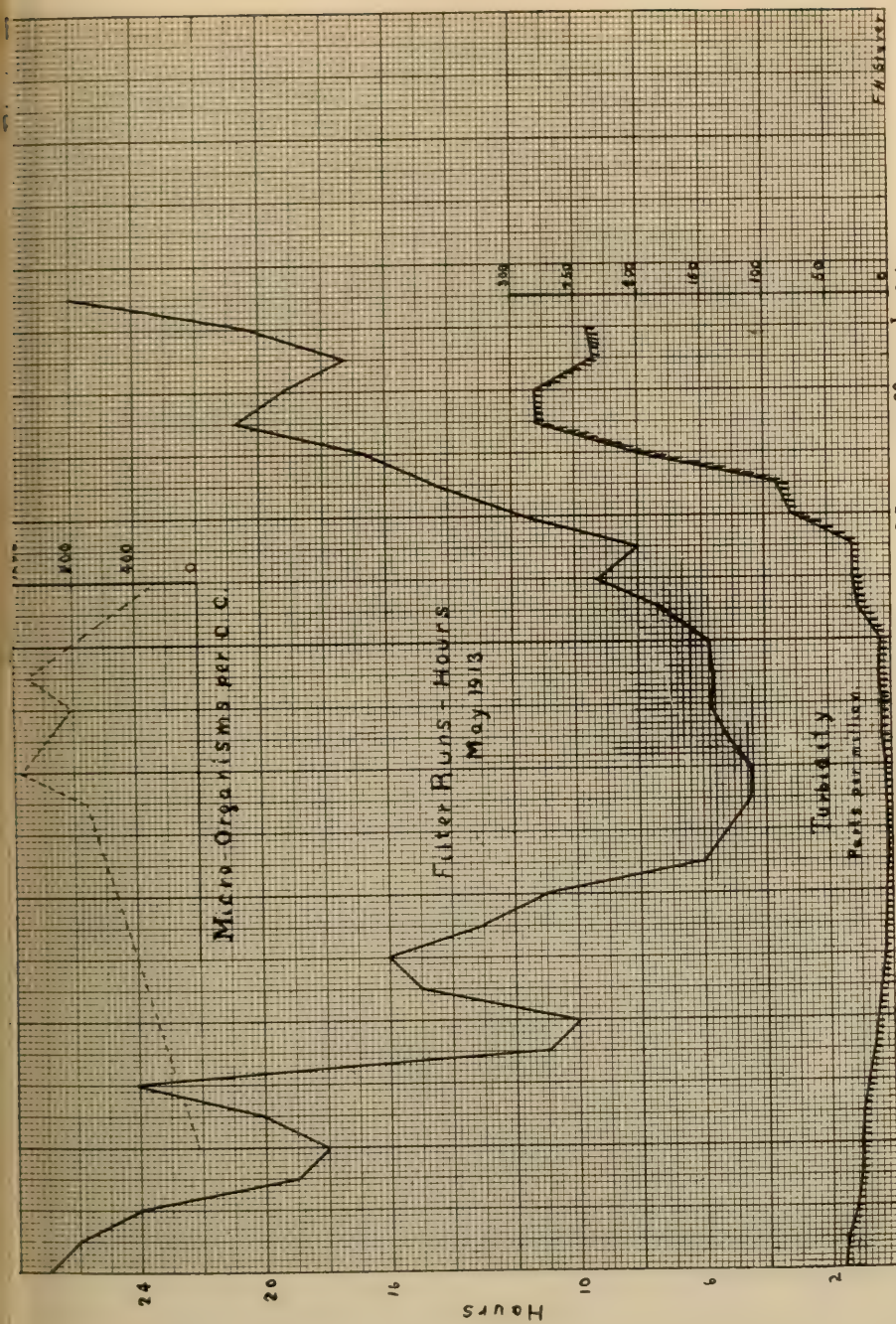


Plate III
Micro-Organisms per c.c.
1000
500
0
Filter Runs - Hours
June 1912
Hours
30
26
20
16
10
6
4
Turbidity
Parts per million
200
150
100
50
0
Parts per million
Cu SO4 Applied
Water Not Sedimented.
June
25
21
19
17
15
9
7
5
3
1


Micro-Organisms per C.C.
Filter Runs-Hours
May 1913
Turbidity
Parts per million
Hours
Water not Sedimented
Direct from river
MAY 1
June 1
F.H. Stover

DISCUSSION

Mr. Theodore A. Leisen: In Louisville there never has been anything particularly offensive in or about the filter in connection with the removal of the microörganisms or the washing of the bed at such times. Short runs produced by the rapid clogging of the beds from microörganisms is an unfortunate condition which so far has not handicapped the filtration work in any way except to make the washings unduly frequent, increasing slightly the average amount of wash-water required, which the speaker hardly thinks is a very serious question.

Mr. John M. Diven: Can you tell what the microörganisms were, Mr. Stover?

Mr. Frederick H. Stover: About 50 per cent asterionella; some synedra and mellosira. The diatoms usually comprise from 60 to 90 per cent of the total number of organisms present. Probably about ten or twelve per cent of the total would be algae of various kinds.

Mr. Theodore A. Leisen: The unfortunate feature about the matter is that the effort to overcome this trouble by the use of copper sulphate results in a very high bacterial content in the filtered effluent, which however is not in any way dangerous, as these bacteria are all saprophytic organisms, but it looks bad on the record.

Mr. W. H. Durbin: We had at Evansville a siege of microörganisms between the dates of May 15th and May 26th, similar to those just cited at Louisville.

During this time our wash water ran as high as 10 per cent and although we fed hypo ranging from 6 to 10 pounds per million gallons, still we were bothered with an after growth in the filters. Normally our count on gelatine was well below 100 per c.c., but during the above time the count ranged from 500 to 1000 per c.c. These however were not pathogenic in form but tend to make the reports show up badly.

The question as to how best to handle these organisms is going to be a very important one with us since the capacity of our plant has been about reached.

Mr. G. G. Earl: Papers of this character are most helpful to operators, and everyone should feel grateful to any plant that gives out its practical experience and its troubles in order to assist others. New Orleans has been very fortunate, especially in the matter of wash water, which has only averaged about one-half of one per cent. of the water filtered for the last three years, and has very rarely exceeded one per cent. There are once in a while what are considered to be after growths in the filters, due to algae growths, which give additional food for the development of bacteria in the same. It was more for sentiment than other reasons, and for the appearance of the thing, that any steps were taken toward reducing them. There has been in New Orleans the same experience that is noted in the paper with regard to the increase of number of bacteria in the effluent following shortly after the addition of hypochlorite, which has been used on several occasions with a view of trying to keep the bacterial counts in line with results that are shown in some reports. But the speaker really has the feeling that it is not worth while, unless there are coli or some other indication of danger, and that very likely it would be better for everyone if they did not try to compete so much in the way of holding down the number of harmless microörganisms. There is one thing that has always been a puzzle in New Orleans; there is a small amount of algae growth on the filter walls and on the coagulating reservoir walls with turbid water. The clear water reservoirs on the New Orleans side of the river are covered, and of course have no algae growths in them. No special clear water reservoir for the Algiers side was constructed, however, and temporarily one of the four compartments of the open coagulating basins is used as a clear water reservoir; and, strange to say, in the three years that this plant has been in operation there has never been a trace of algae growth in the single open compartment used for clear water, although there is algae growth to a slight extent forming on the walls of the turbid water compartments of the coagulating reservoir.

President Gwinn: Is that due to the fact that the water is retained in the Algiers reservoir so much shorter time than it is in the others?

Mr. G. G. Earl: No, the water is not retained in this basin any less time than it is in the coagulating basins. This open clear water reservoir is filled at night and only a little drawn out in the day

time. The filters at both of the New Orleans plants respond automatically to the demands of the pumps to the limit of the maximum safe capacity of the filters, and that capacity as yet is in excess of the maximum pump demand. It would therefore be possible to operate without any clear water reservoir other than the small clear water well under the filters, and since the topography at New Orleans requires low lift pumping to store water in the clear water reservoirs, they are only drawn down a little every day, with a view of gradually changing their water. They stand ready to give water to the pumps automatically if the filter yield falls below the pump demand, but the automatic connection as yet is only brought into action when some of the filters are cut out of service.

It would seem, therefore, that if clear water exposed to light will develop algae growths, this water should certainly do so, and no reasonable explanation has been offered to account for the fact that the treated water in the coagulating basins, which ranges from 300 to 1500 parts per million in turbidity shows growth of algae on the reservoir walls while the perfectly clear water alongside of it in a similar open reservoir has not shown a trace of such growth in three years.

Mr. Dow R. Gwinn: When you have trouble of that kind, wash one of the filters thoroughly, and then allow it to stand for a few days so as to have the benefit of the air in the bed. By allowing the air to get at the bed it may have the effect of oxidizing the microörganisms.

Mr. John M. Diven: Mr. Gwinn's suggestion was a very good one, but when you are having algae troubles with filter beds it is always at a time when you have to crowd your filters to their utmost capacity, and when, therefore, you cannot allow one to stand idle for one single second, unless you have built a plant that is ten times the ordinary capacity.

President Gwinn: New Orleans has a plant of that kind.

Mr. C. Arthur Brown: The speaker would say that the suggestion made by President Gwinn is one that we tried out at Lima, and, instead of working out as he suggests it made the matter worse.

Mr. W. C. Lounsbury: Is it not true that the experience of our members has been that treatment with hypochlorite or chloride of lime retards the growth of bacteria, but that there are heavy aftergrowths of bacteria as a result of such treatment?

Mr. C. Arthur Brown: The Lima case offers a direct answer to that. Water going into the clear well, under the best conditions that we could establish there at that time, had a content of about 300, and on passing out about 2800, on the average, after treatment with hypochlorite, without any regard to the algae at all.

THE WATER PURIFICATION PLANT AT FARGO, NORTH DAKOTA

By Frank LaF. Anders

While the art, design and operation of water purification plants in Europe and the eastern part of the United States have undergone rapid changes and made many advances it is a comparatively new acquisition to the lines of endeavor of western municipalities. The reasons for this are not obscure; the east has been settled for many years and though the supply of good water was ample it has become contaminated by the increase of population on the water sheds. On the other hand the western half of the United States is hardly fifty years old and many of our principal cities cannot boast half that age. The development of the west is one of the most remarkable periods in the history of mankind especially when we consider that those improvements that formerly took centuries and decades for acquirement have been brought into this new country within the period of one generation. No public improvements have been too good for its cities and great expenditure has been made in order that its population should enjoy the same conveniences that their eastern sister cities enjoy.

Notably among these public improvements are those of sanitary sewerage system and public water supplies. Both these conveniences and necessities can be found in a great majority of our northwestern towns and cities, and the town is indeed considered backward that, when it has reached any size has not given some consideration to those two important subjects.

The rapid increase of population on the water sheds and on the drainage areas from which the supply of water for western cities must be obtained has opened up a large field for the purification of public water supplies. Of course many municipalities obtain water from wells, but in some cases this is unsatisfactory for various reasons. The supply in cases is limited and in many is unsanitary. Surface supplies are much more satisfactory because they are adaptable to purification by modern methods and when so purified produce a more palatable and useful water than the supply from wells.

During the past five years there have been several water purification plants constructed in the northwest. The plant in the city of

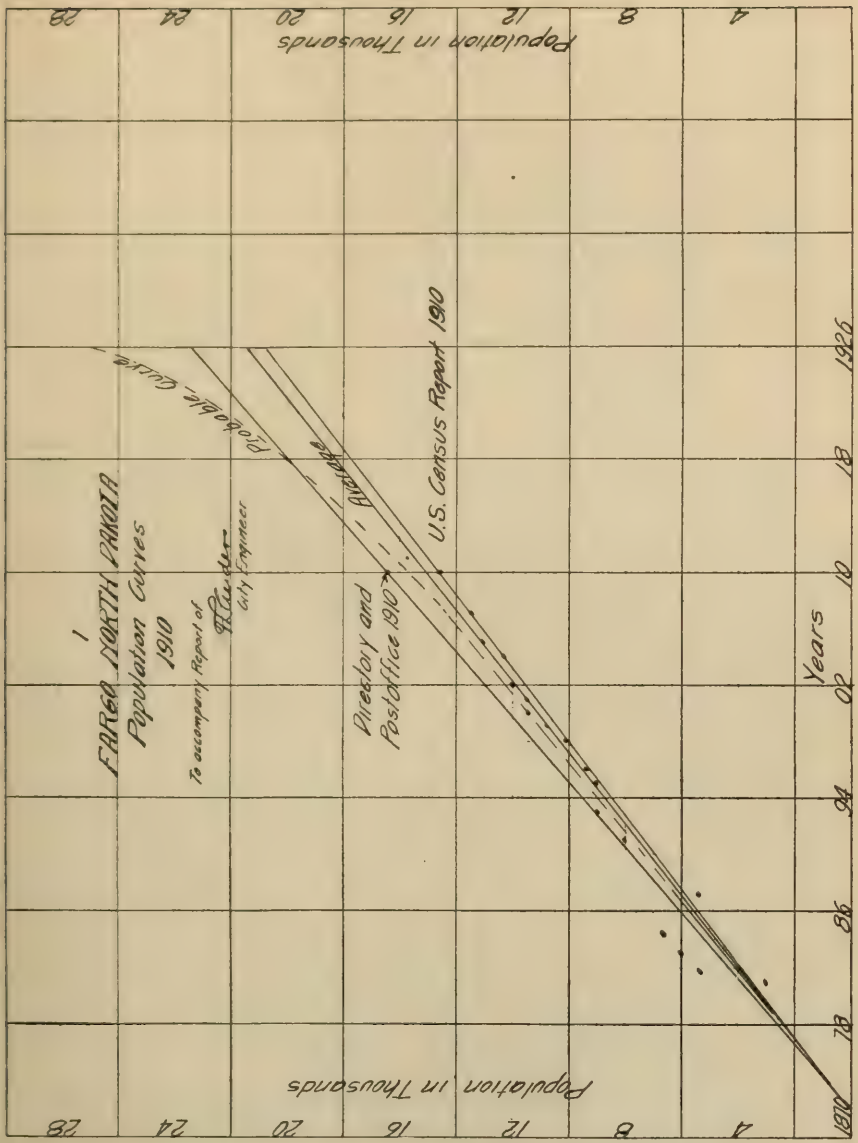
Fargo, N. D., is not a large one, its capacity when operating under normal conditions being 4,000,000 gallons per twentyfour hours, but its success has been so marked and extraordinary that its character has seemed worthy of a description at this time.

Fargo is a city of about 16,000 population located in what is known as the Red River Valley in eastern North Dakota and western Minnesota. The valley is of glacial origin and geologists tell us that a great sheet of water known as Lake Agassey once covered this region. A section of the valley from east to west reveals from 6 inches to 6 feet of soil underlaid with clay, sand and gravel to a great depth. The Red River of the North rising in the Lake Park region of Minnesota finds its way into the valley at the southern end and follows it by a winding course northward to Lake Winnipeg.

Before the country became so thickly settled the water from the river was fair enough to use but for the past twenty years water from other sources had to be obtained for domestic purposes. These methods of supply were always unsatisfactory in the extreme. Many investigations were carried on by various engineers but for several reasons the time was not ripe for the construction of a purification plant. During the fall of 1910 investigations were made by the city council and the writer as to the feasibility of the purification of the water of the Red River of the North for public purposes and in December of that year the writer was instructed to design a plant as suggested by the investigations made. Ground was broken on June 15, 1911, and the plant went into operation June 13, 1912.

Many things peculiar to this region were taken into consideration in the design of the plant. The water was considered too hard, the hardness running from 200 to 500 parts per million, depending on the season of the year. The flow in the river has been as low as 30 feet per second and on several occasions has probably discharges in excess of 7000 feet per second. The large discharge is always during the spring and at that time it becomes very highly colored and the turbidity is increased many times, due to suspended clay being carried in a large amount. At these times the bacterial contents increase many fold from increased drainage from farmyards and cesspools. B. coli are found in all 1 cubic centimeter samples. During the spring of 1913 the bacterial content of the water increased from 1000 to 86,000.

Due to the fact that the water was so hard it was determined to soften the water as well as remove the color, odor, turbidity and


FARGO NORTH DAKOTA
Population Curves
1910
To accompany Report of
H. Ruder
City Engineer
Probable Curve
Average
Directory and
Postoffice 1910
U.S. Census Report 1910
Population in Thousands
Years
1880
86
92
94
02
10
18
1926
4
8
12
16
20
24
28

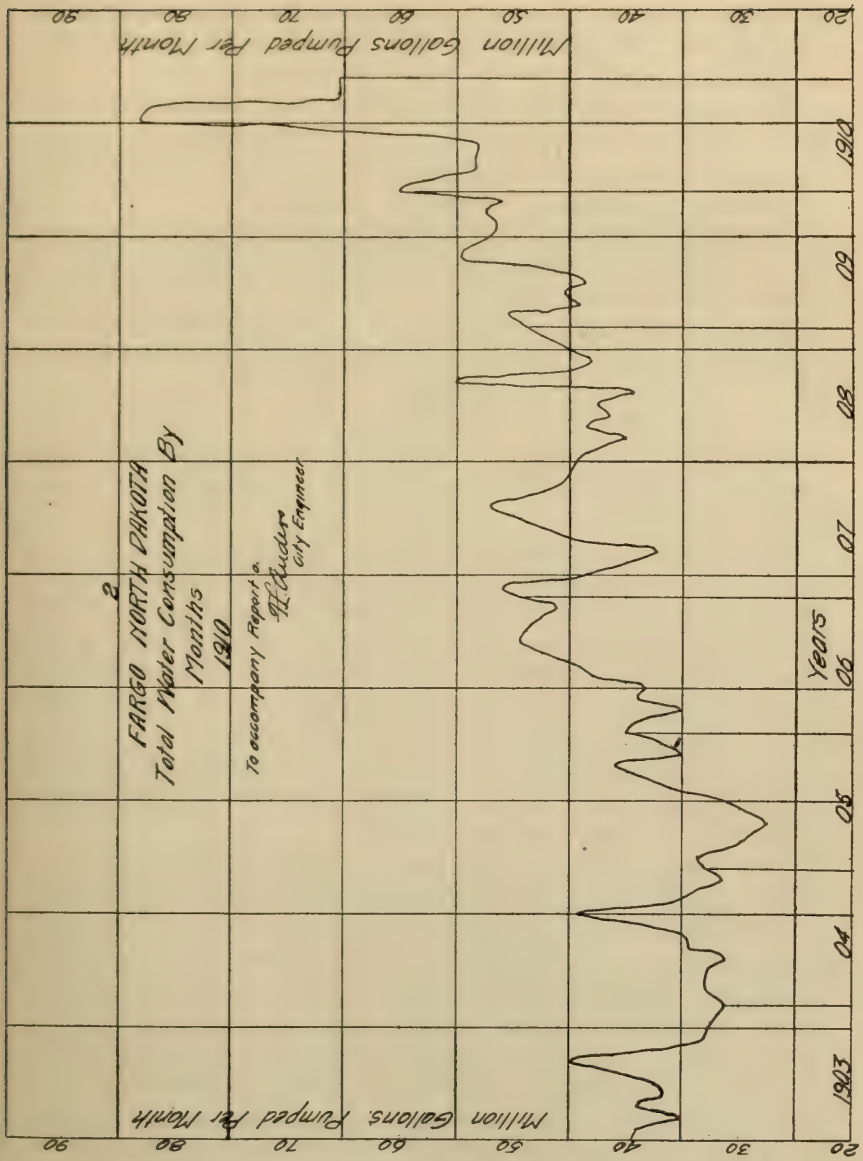
bacteria. How successful this has been done can be seen from an examination of the tables given with this paper.

The plant is located up the river from the city and near its southern limits. This site was the very best available from the sanitary viewpoint, it having only one disadvantage, being one mile from the nearest railroad shipping point. This means that coal and chemicals will necessarily cost somewhat more than if the plant was located in a more advantageous position.

The intake is about 800 feet east of the plant and is built of sheet piling. The inlet is protected by an iron sheet perforated with onefourth inch holes. The wet well is located about 50 feet from the intake and is connected to it by two lines of 18 inch cast iron pipe. The wet well has two compartments each fitted with gate valves for cleaning purposes. The connection to the low service station is a cast iron flanged pipe suction line 18 inches in diameter and having a length of about 750 feet. The low service station is a concrete circular well 25 feet deep and 22 feet in diameter. In it are located two centrifugal pumps driven by steam turbines. The steam pressure is 150 pounds and the turbines exhaust into a surface condenser maintaining 26 inches vacuum. When the machines are running 1500 revolutions per minute they will pump respectively 3,000,000 and 4,000,000 gallons of water per day.

The discharge from the low service pump is delivered through an 18 inch line about 80 feet long directly into the first chamber of the mixing baffles. The mixing chamber is a rectangular concrete structure 53 feet 6 inches long, 21 feet 7 inches wide and 20 feet deep. The baffles are the vertical type giving an over and under flow. They are about 3 feet square in section and the water in passing from inlet to outlet travels over 2600 feet. The purpose of this arrangement is to keep the water in a state of agitation as well as thoroughly saturate the lime and iron solutions in it. This is accomplished in a very marked degree, and the results obtained are most highly satisfactory. The sedimentation basins are two in number, each being about 50 by 150 feet in area by 14 feet deep. The effective volume of basin No. 1 is reduced by the mixing chamber which is located in its southwest corner.

The system of mixing chambers and sedimentation basins when considered as a whole is very flexible there being eight separate and distinct methods by which the water can reach the filters after leaving the low service pumps. Some of these routes have been found very useful and some have not been given any trial as yet. The


Million Gallons Pumped Per Month
20
30
40
50
60
70
80
90
1903
04
05
Years
06
07
08
09
1910
FARGO NORTH DAKOTA
Total Water Consumption By
Months
1910
2
To accompany Report of
R. L. Cutler
City Engineer

efficiency of this part of the plant is very high. The hardness of the water has been reduced all that it can be, which is about 50 per cent and the bacterial removal in the basins has been as high as 97.5 per cent and is rarely down to 95 per cent.

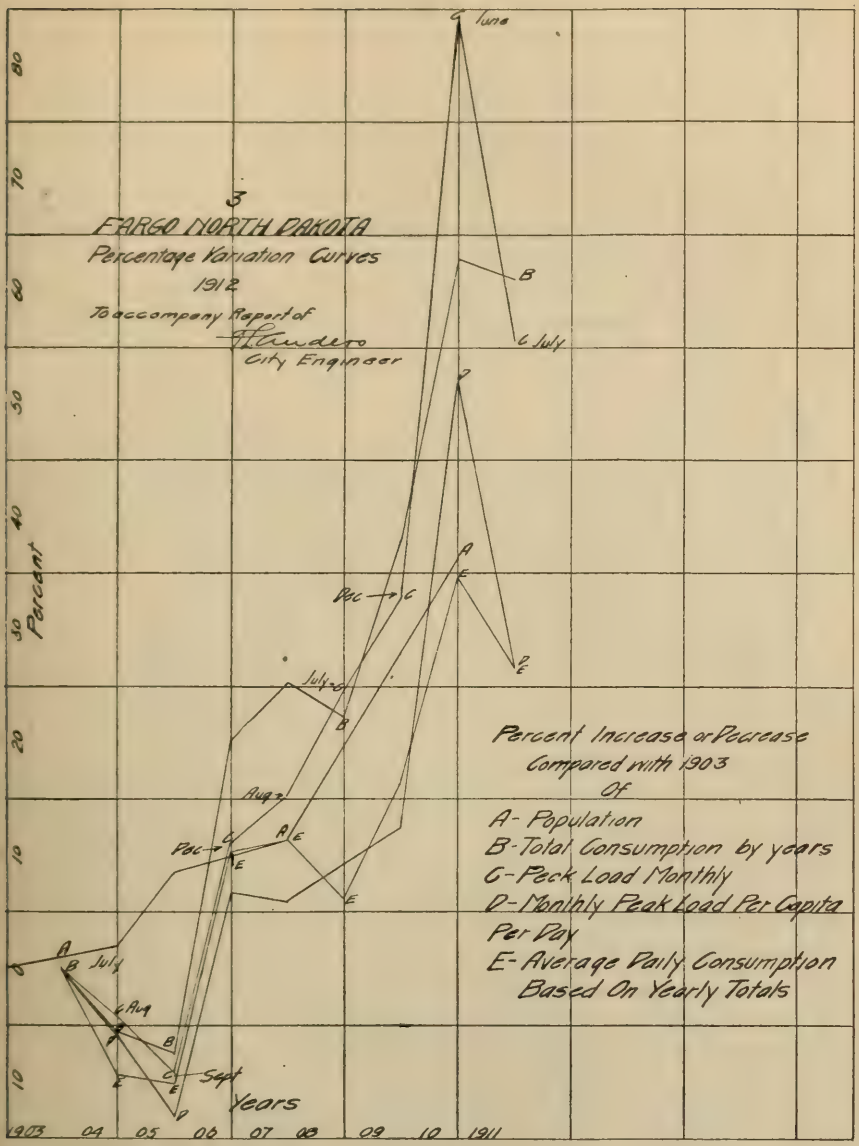
When operated under normal conditions the coagulant is added in the pipe line about forty feet from the discharge into the mixing chambers, the lime and soda at the latter point and the hypo while the water is passing from the basin to the filter.

The conduit from the basin to the filter is a rectangular concrete structure having an area of about 25 feet in cross section. In front of each filter there is a forebay fitted with influent and sewer valves. The filter being in operation the water passes through the influent valve into the forebay thus through the wash trough opening following the wash troughs to the sand beds. The manifold system is covered with 10 inches of gravel graded from $\frac{3}{4}$ inch down in four sizes. The sand bed lies on top of this and is 30 inches in depth, Red Wing filter sand is used having an effective size of .4 mm, and a uniformity coefficient with 1.4 mm.

This plant has a dry pipe gallery, the floor of which is the clear water conduit. On either side of the conduit there is a sump for receiving the wash water. Above the sumps are located the pipe, valves and fittings for wash water, filtered water and sewer drain from the forebay. The clear well is located directly below the filters and pipe gallery. The design is such that there is no dead water space, there being continuous circulation from the filter to the suction of the high service pumps. The capacity of the clear well is small there being an available storage of about 160,000 gallons but this has been found ample.

The filters are rectangular 17 feet by 21 feet and 7 feet deep and have a normal rating of 125,000,000 gallons per acre per day. The filter controllers are fitted with electrical control. They are operated by an accelerator placed in effluent lines to the clear well. These controllers are primarily actuated from the clear well and have proven successful in every respect. The filter controllers keep the stage of the well always nearly a maximum without any attention from the operators. The filters normally are always in operation except when out for washing. A test was made when the plant was filtering about 7,000,000 gallons per day and the efficiency was not in any way affected by this rate.

The head house is located on the west end of the filter gallery. It is a two story and basement structure of concrete brick and tile.


3
FARGO NORTH DAKOTA
Percentage Variation Curves
1912
To accompany Report of
Flandro
City Engineer
Percent
80
70
60
50
40
30
20
10
0
June
July
Aug
Sept
Dec
Years
1903
04
05
06
07
08
09
10
1911
A
B
C
D
E
Percent Increase or Decrease
Compared with 1903
Of
A- Population
B- Total Consumption by years
C- Peak Load Monthly
D- Monthly Peak Load Per Capita
Per Day
E- Average Daily Consumption
Based On Yearly Totals

The walls are common brick faced with red Twin City interlocking terra cotta tile. All interior construction is concrete, the only wood being the doors, windows, roof sheathing and casing. The roofs are deep green glazed tile.

In the basement are located the baths, toilets, wash water pumps and the repair shop. The pipe gallery is at the same elevation as this floor. On the first floor is located the laboratory and the chemical feed controllers. The filter gallery is the same elevation as this floor. The chemical tanks extend downward from the second floor to an elevation 5 feet above the first floor.

The second story of the head house is the chemical storage and solution room. The north end is used for storing coagulants, soda, lime and hypo. In the south end the chemical storage tanks extend through the floor 4 feet and being covered with a concrete slab form a raised platform. Here the apparatus for stirring the chemical solution is installed. There are duplicate tanks for each solution and motor driven agitators are installed for the coagulants, lime and hypo. Soda is not regularly used hence no agitators were installed. Each tank is equipped with depth gauges. The capacity of the various solution tanks is as follows:

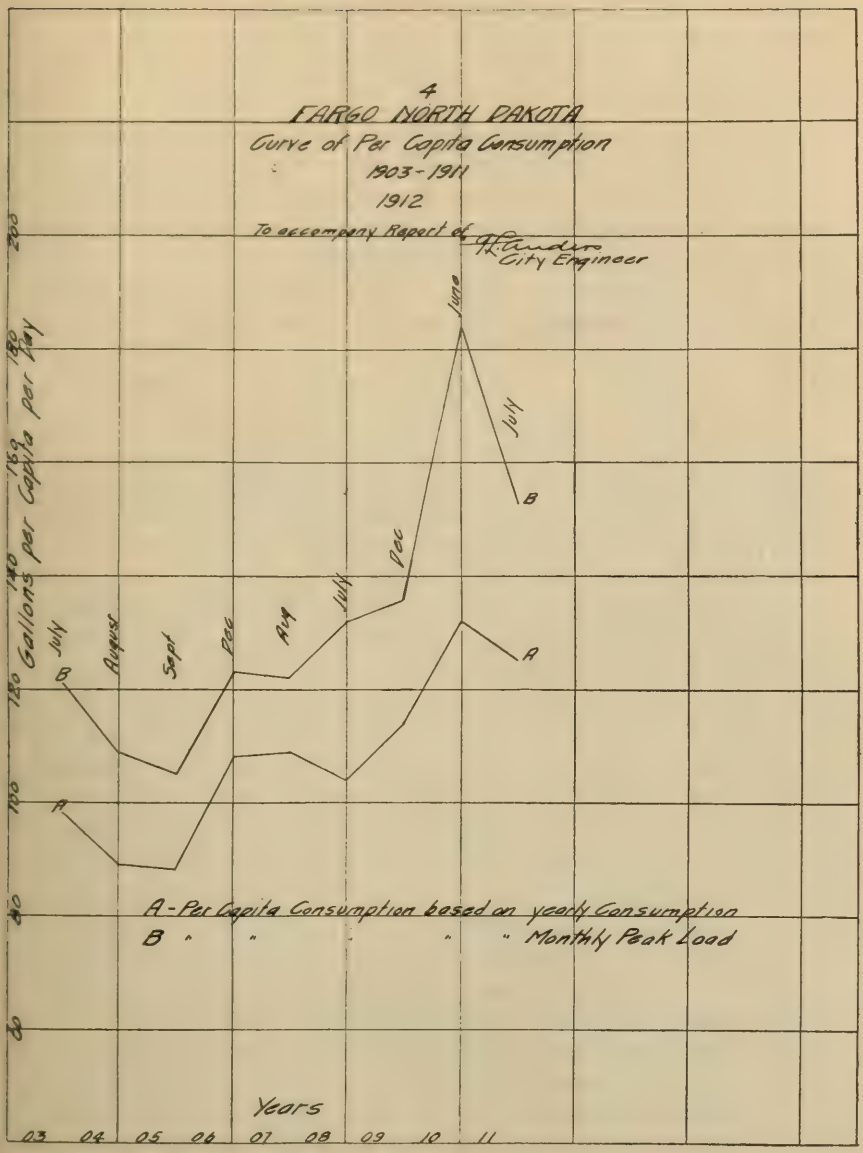
Lime	12,700 gallons.
Coagulant	2,500 gallons.
Hypochlorite	790 gallons.
Soda	2,500 gallons.

The regulation of the flow of chemical solution to the raw water is through the means of the chemical feed controllers and in many respects is the same as that installed in Minneapolis, Minn., the principles being identical. The primary actuating force is obtained through an accelerator placed in the raw water, fitted with a Pitot tube and piezmeter.

These controllers have given excellent satisfaction with very little attention and no repairs. This is also true of the rate controllers on the filters. All loss of head and elevation gauges on the filters, clear well and sedimentation basins are fitted with rectangular abscissa and coördinates.

At the present writing the coagulant used is sulphate of iron although a small quantity of alum has been used for test purposes. The amount varies from one to three grains per gallon, the larger amount being used during the spring freshet.

The amount of hydrated lime for water softening used varies from


4
FARGO NORTH DAKOTA
Curve of Per Capita Consumption
1903-1911
1912
To accompany Report of
City Engineer
Gallons per Capita per Day
200
180
160
140
120
100
80
June
July
B
A
July
Aug
Sept
Dec
A-Per Capita Consumption based on yearly Consumption
B " " " " " Monthly Peak Load
Years
03
04
05
06
07
08
09
10
11

5 to 10 grains per gallon. Larger amounts than 10 grains were used at certain periods of the test which took place in November, 1912, and January, 1913.

About one twentieth of a grain of hypochlorite is used under normal conditions.

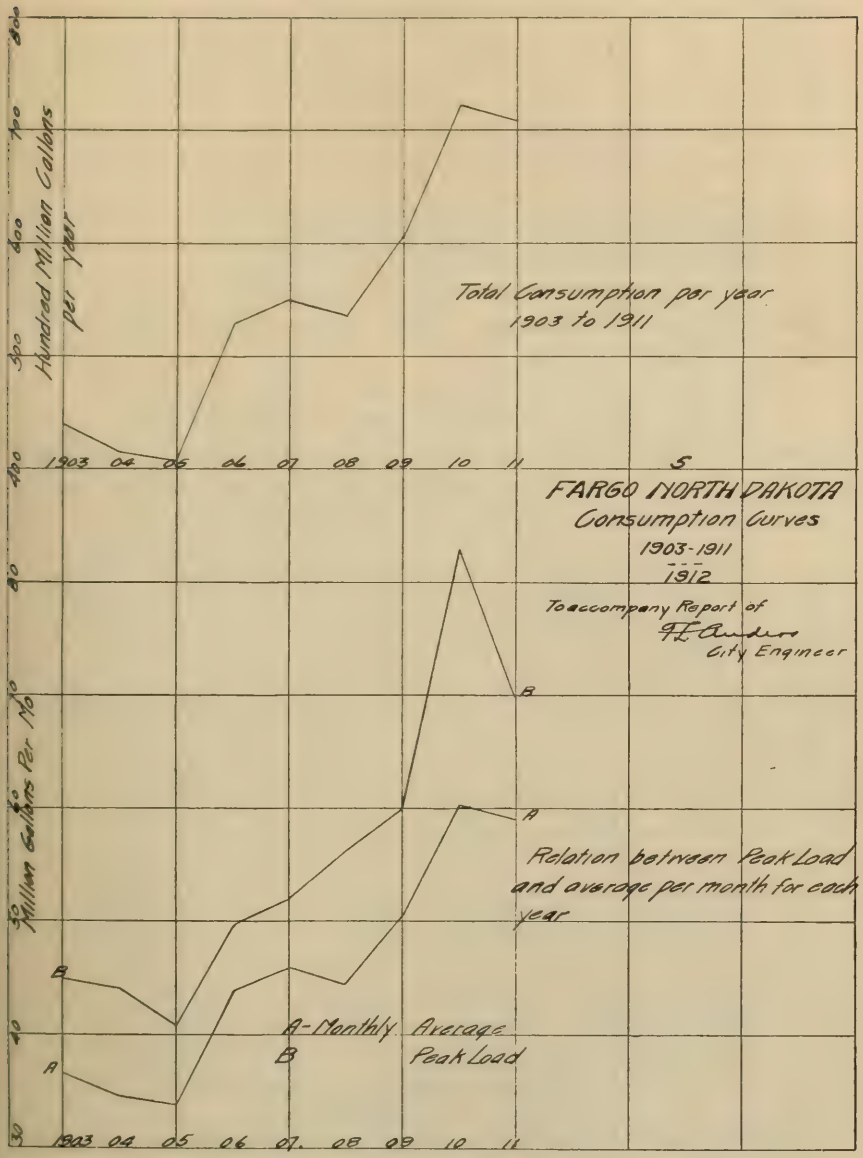
The laboratory is very complete in all its appointments. All routine analyses are made here under the supervision of the superintendent of filtration. At least one chemical and bacteriological analysis is made each day and if it is deemed necessary more are made as a check and for further information.

A study of the data on the plant shows some remarkable results. As has been before stated the removal in the basins runs on the average over 97 per cent and we believe that this is due to their design in connection with the mixing chamber. This efficiency in the basins has, no doubt, decreased the amount of wash water used until at present it is less than 1.4 per cent. This will be reduced in time as the operation of the plant on this water is better understood. The loss of head through the baffles varies and reaches a maximum of about 4 feet when pumping at a rate of about 7,000,000 gallons per day.

The accumulated material in the sedimentation basin is removed by the aid of the sludge valves and a sewer system. The floor of the basin is flat. Numerous valves have been installed and to date there has been no difficulty in cleaning the sediment. The procedure is about as follows: The valves are opened up and the basin drained. A $2\frac{1}{2}$ inch hose with $1\frac{1}{8}$ inch nozzle is then run down through the manholes and by following up the sludge and keeping it fluid it can be removed in about five hours. The monthly accumulation is about 7500 cubic feet. This material is discharged into an 18 inch sewer 3000 feet in length and discharged to the river.

The washing system of the filter is very efficient; there are two wash troughs 21 feet long, the maximum travel of the wash water is 39 inches. Ample area has been given the troughs in order that the maximum amount of wash could be carried off.

The high service is located just north of the filter plant. It conforms in appearance to the filter plant. The building is 93 by 53 feet, a brick wall separates the boiler rooms from the pumping room. The boiler room equipment consists of three water tube boilers of 150 horse power each. The steam pressure is 150 pounds. Excellent service has been obtained from these boilers and the evaporation exceeds 8 pounds of water per pound of coal as fired.


Hundred Million Gallons per Year
Total Consumption per year 1903 to 1911
1903 04 05 06 07 08 09 10 11
FARGO NORTH DAKOTA
Consumption Curves
1903-1911
1912
To accompany Report of
F. E. Anders
City Engineer
Million Gallons Per Mo
B
A
Relation between Peak Load and average per month for each year
A-Monthly Average
B Peak Load
1903 04 05 06 07 08 09 10 11

Youghiogheny screenings is the coal used. The other equipment consists of two boiler feed pumps, one water weigher, a feed water heater and auxiliary apparatus. The pumping equipment consists of two units. The main unit is a cross compound, crank and fly wheel, high duty pumping engine of 4,000,000 capacity per day. When under test this pump gave 131,000,000 foot pounds per 1000 pounds of steam with a vacuum of 27 inches in the condenser.

The second unit is a duplex tandem compound pump of a capacity of 3,000,000 in 24 hours. It is run condensing.

The plant has its own light and power generators, these consist of one 20 k. w. and one 15 k. w. direct current 110 volt units direct connected to vertical engines. The average current used in the plant is about 50 amperes.

The Red River of the North is a variable stream in its flow and from year to year may change its level as much as 35 feet. The plant had necessarily to be located so there would be no danger of putting the plant out of commission. The following elevations are given of various stages of the river, elevations being sea level.

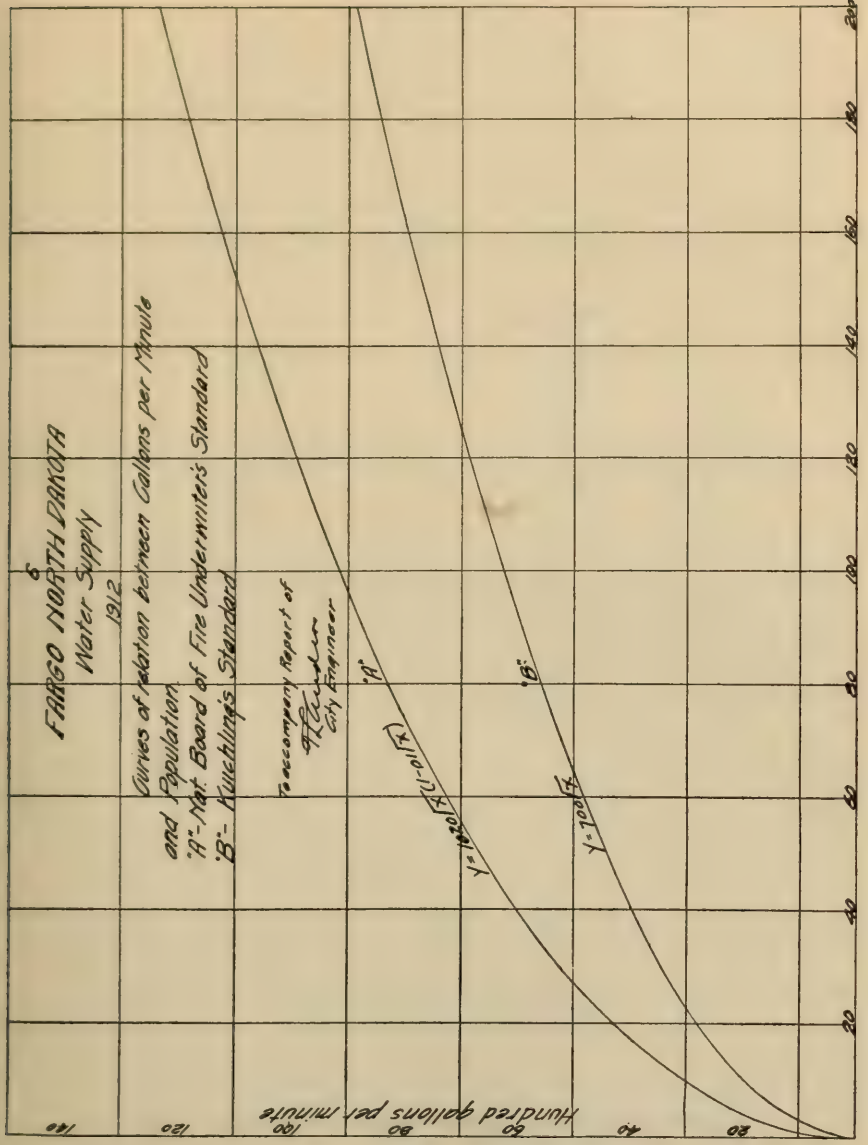
River bed	864
Present elevation water surface	875
Elevation in 1897	905.5
Highest ground elevation in the city	905.0

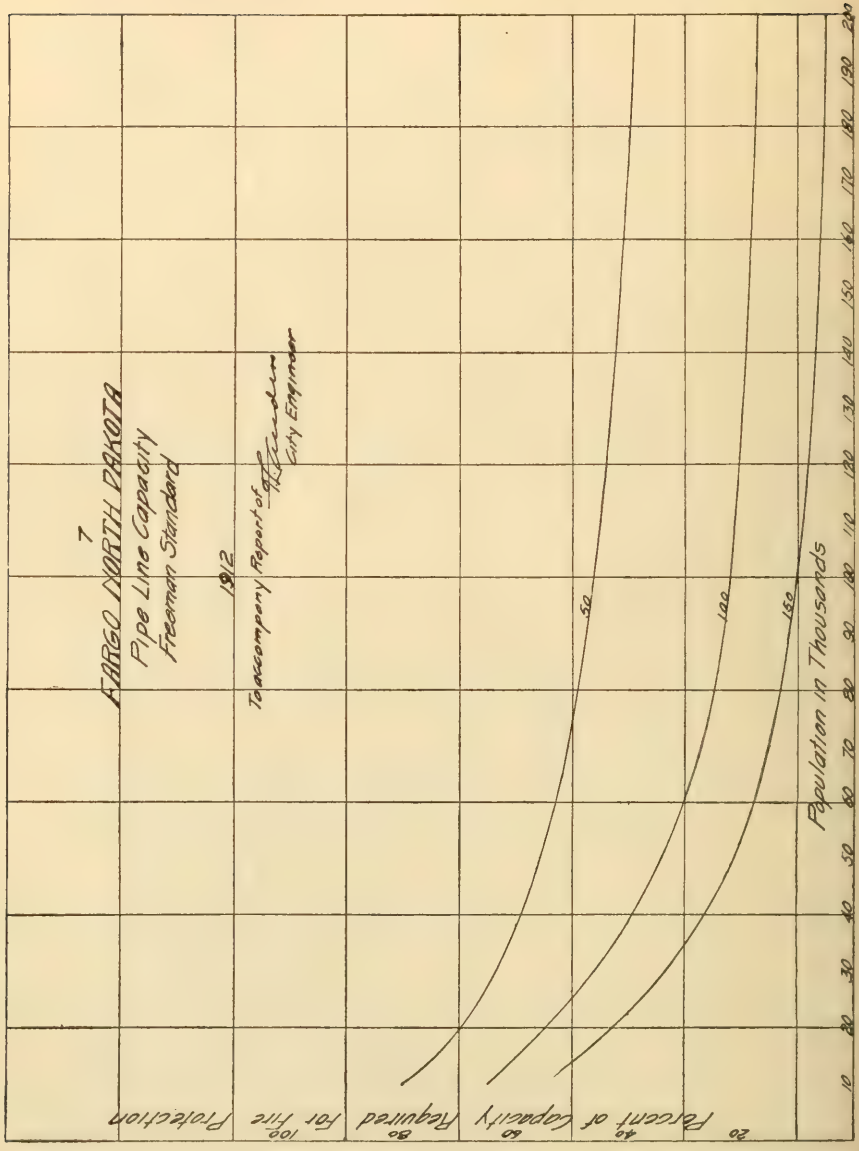
The following elevations are given for the various parts of the plant:

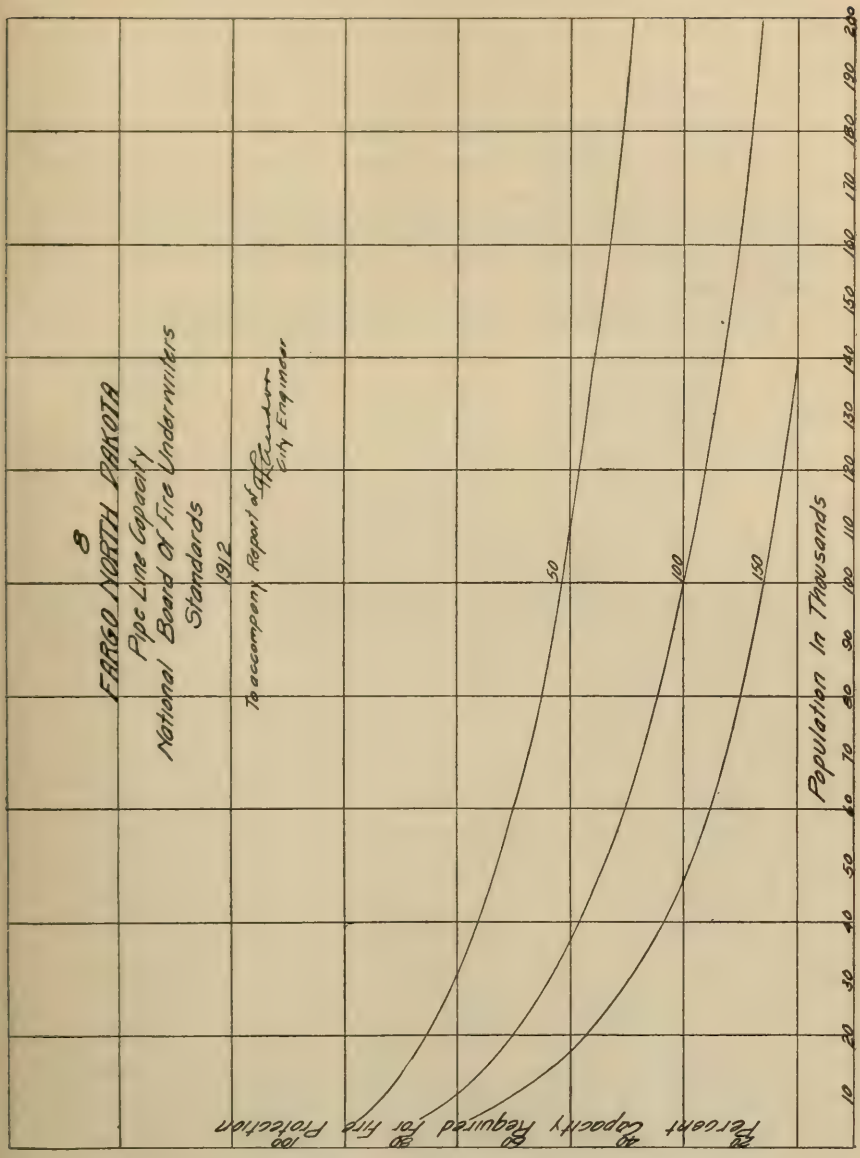
Center of suction for low service pumps	882.10
Floor of low service pump pit	880.00
Maximum elevation of water in mixing chamber	912.00
First floor of head house	910.00
Basement and pipe gallery floor	897.50
Floor of clear well	890.50
Head house, second floor	923.0
Top of solution tanks	927.5
Floor of pumping station	906.0
Center line of suction of high service pumps	908.0

The chimney of the plant is a concrete and brick structure 100 feet above the grates in height and is 54 inches in diameter.

The force main to the city is cast iron class "B" pipe 18 inches in diameter and 3600 feet in length. It is fitted with a Venturi type


FARGO NORTH DAKOTA
Water Supply
1912
Curves of relation between Gallons per Minute
and Population
"A"- Nat'l Board of Fire Underwriter's Standard
"B"- Kuichling's Standard
To accompany Report of
H. Russell
City Engineer
"A"
"B"
$Y = 1020 X^{(1-.01 X)}$
$Y = 100 X^{.5}$
Hundred gallons per minute
20
40
60
80
100
120
140
160
180
200


7
FARGO NORTH DAKOTA
Pipe Line Capacity
Freeman Standard
1912
To accompany Report of
City Engineer
52
100
152
Population in Thousands
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200
Protection
For Fire
Required
Percent of Capacity
20 40 60 80 100


8
FARGO NORTH DAKOTA
Pipe Line Capacity
National Board Of Fire Underwriters
Standards
1912
To accompany Report of Assistant
City Engineer
50
100
150
Population In Thousands
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200
20 Percent Capacity Required for Fire Protection
50
100

meter located just outside the station. This meter is complete with indicator register recorder, and is valuable in giving a graphic record of the consumption of water at various times. It thus appears that Fargo is a large consumer and probable waster of water. The population is probably 16,000, there are 2300 connections, 1500 of which are residence connections. There are about 14,000 people using city water, after making deductions for manufacturing and industrial connections the consumption is still over 150 gallons per capita per day. There are not more than 40 meters in the city but it is now purposed to meter the city in order to conserve the water supply.

The cost of the plant complete in operation was as follows:

Filter plant	$105,000
Pumping station	83,000
Water mains	15,000
Miscellaneous	2,000
Sewer	10,000
Total	$215,000

The cost of operation in cents, per 1000 gallons is about as follows, varying somewhat with the season of the year and other conditions:

Insurance	$0.08
Accounting	.26
Maintenance	.26
Interest	.45
Depreciation	.54
Maintenance of Distribution	.64
Interest and sinking fund	2.25
Chemicals	1.40
Coal	1.64
Labor	1.54
Total cents per 1000 gallons	9.06

These figures are based on the plant producing 800,000,000 gallons per year and are the rates under maximum conditions. Many of the items are too high for present conditions but this analysis was made to determine the possible maximum cost. The accompanying curves show the various costs for varying pumpages.

The asthetic deficiency of the raw water as compared with the

filtered water is very marked when the opinion of the consumer is used as a standard. Many who felt they could not use the filtered water are now its most enthusiastic boosters. Something was done they believed could not be done, but now it has been proved to them. They believe it to be the best water in the country. In this alone the consumer has been saved many thousand dollars invested in spring and artesian waters and a more satisfactory water has been obtained.

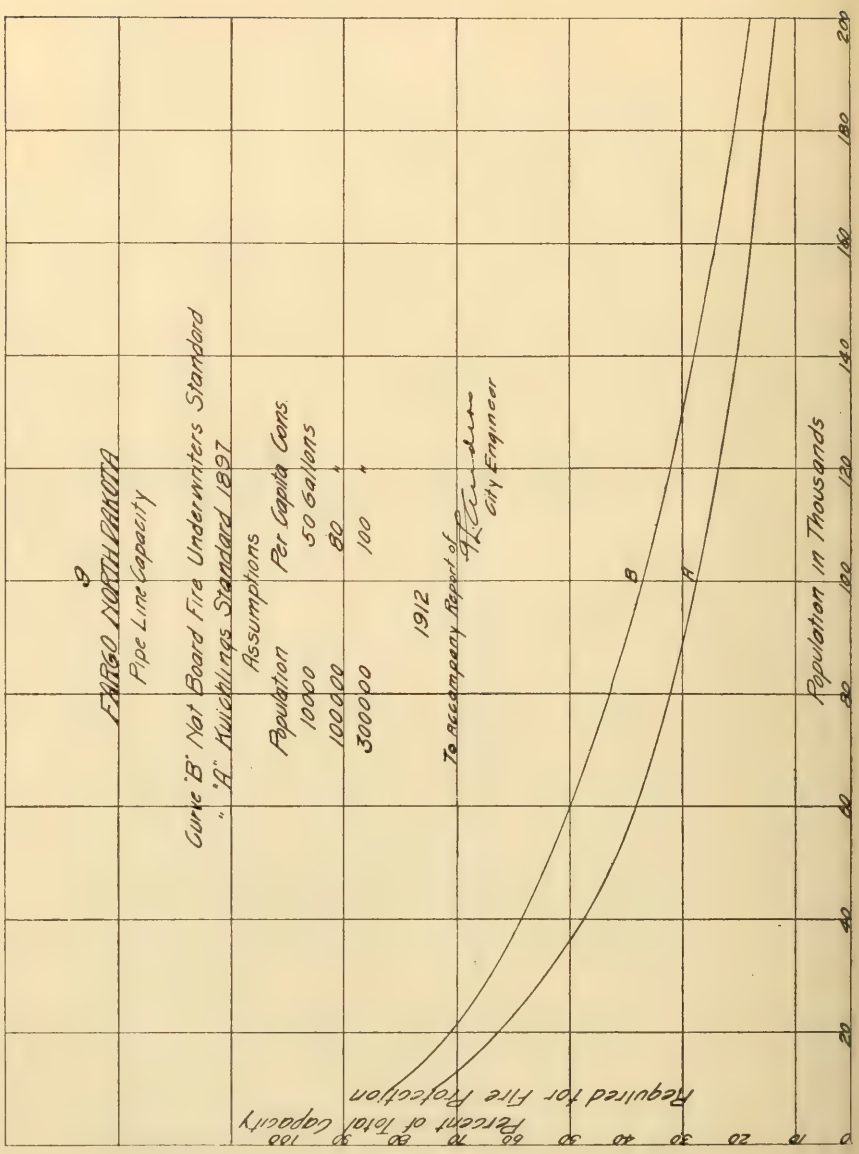
The plant is operated by a chemist and bacteriologist who is superintendent of filtration, who also makes all analyses and has complete charge of furnishing pure water to the city of Fargo. There are three shift operators, three engineers, three firemen and two helpers.

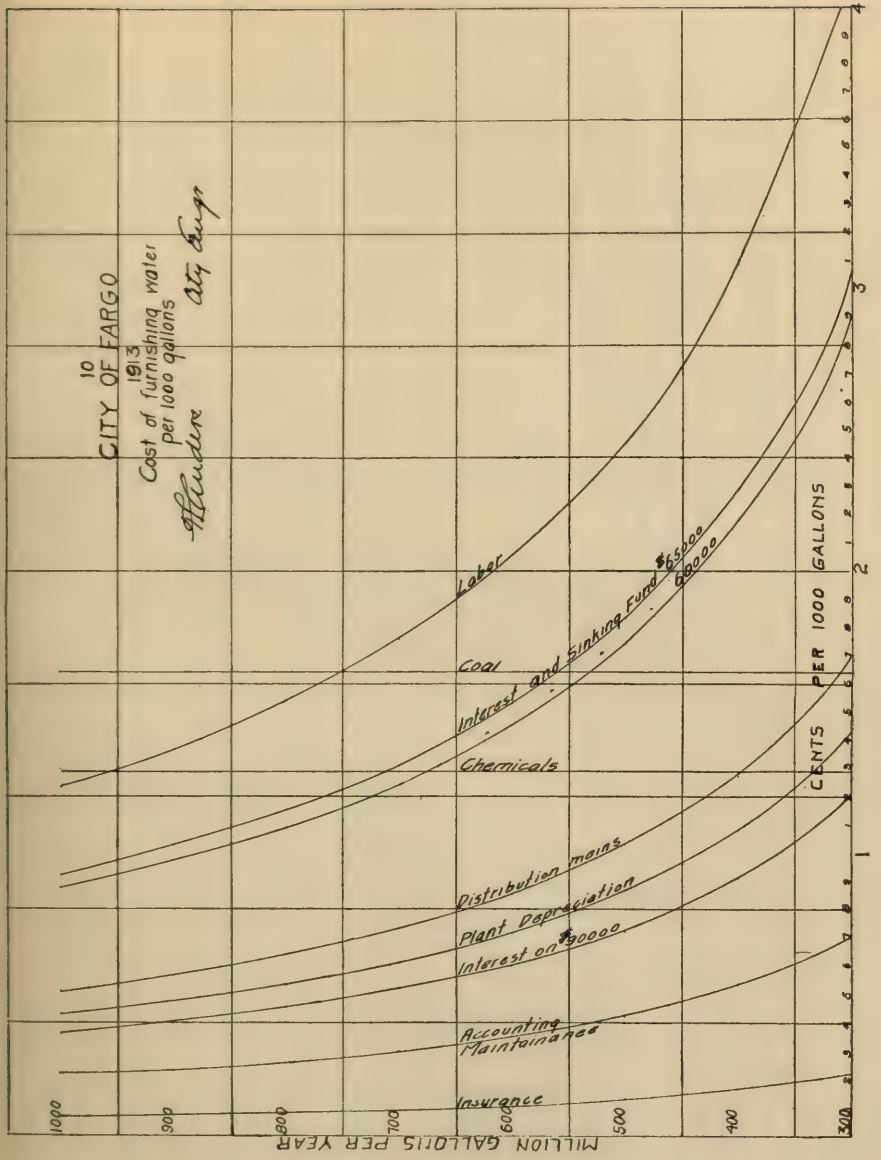
Some studies of conditions represented by curves are herewith shown and will no doubt be of interest in connection with the design and operation of this plant:

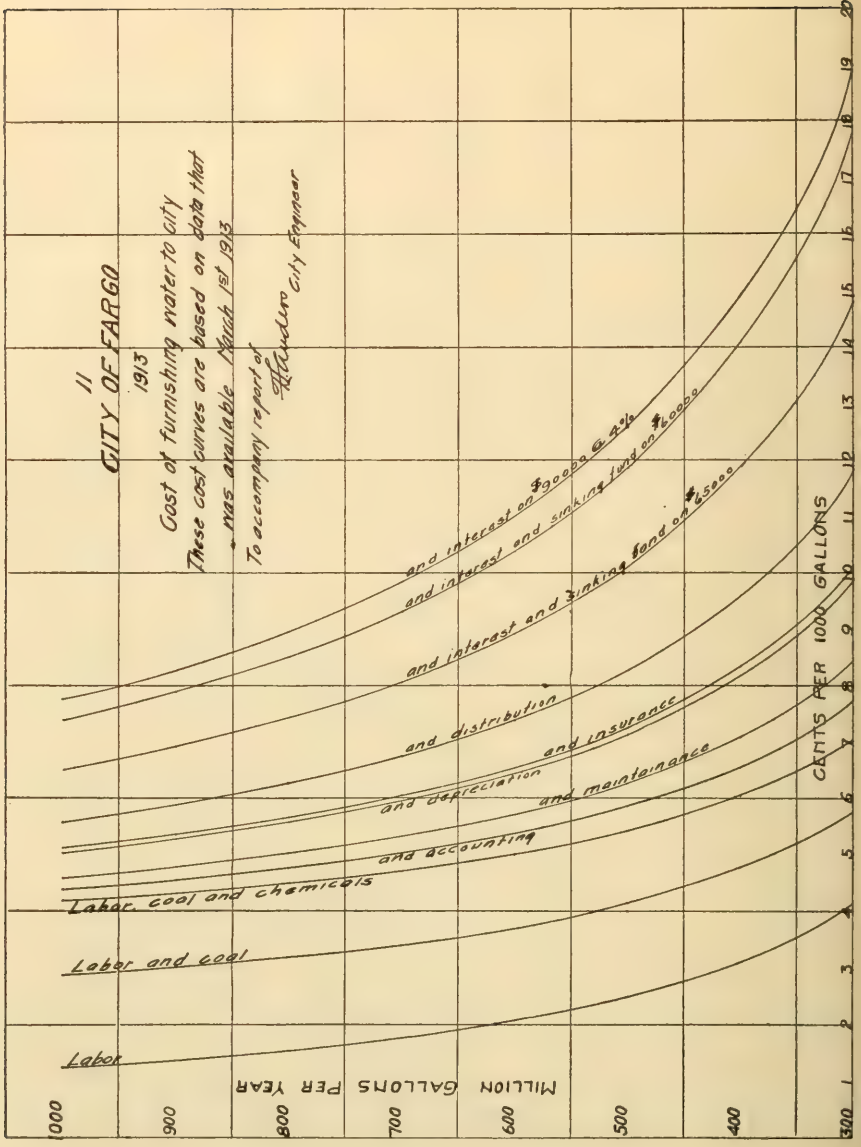
Date	CHEMICALS					BACTERIA								ALKALINITY										Wash water
														Raw			Filtered			Color		Chlorine		Turbidity	
	Fe	Ca	Al	Na	Hypo	Raw	Settled	Clear well	Lab. tap	1	2	3	4	Total	N. C.	B. C.	Total	N. C.	B. C.	Raw	Filt.	Raw	Filt.	
3/1/13	600	4.100		500	17	620+	22—	8—	10—	4—	2—	4—	8—												18,690
2	"	"		"	"																				21,360
3	"	"		"	"	740+	16—	8—	6—	2—	10—	8—	6—	285.5		285.5	148.5	126.	22.5	16	10	7.1	8.7	22	80,100
4	"	"		"	"	800+	22—	8—	8—	4—	2—	6—	0—												
5	"	"		"	"	630+	14—	10—	0—	8—	4—	8—	6—	295.		295.	151.1	132.4	18.7	16	10	7.1	8.7	22	72,770
6	600	"		"	"	780+	24—	8—	10—	6—	6—	8—	2—	301.2		301.2	156.	149.6	6.4	"	"	7.0	7.8	"	56,070
7	"	4,100		"	"	700+	20—	10—	6—	2—	6—	6—	2—	293.8		293.8	155.9	145.4		"	"	7.4	8.0	"	"
8	"	4,050		"	"	800+	20—	8—	8—	4—	2—	8—	8—	286.1		286.1	154.2	140.	14.2	"	"	7.6	8.2	"	21,360
9	"	"		"	"															"	"			"	44,720
10	"	3,900		"	"	622+	16—	6—	10—	2—	6—	6—	4—	287.		28.7	146.7	145.6	1.1	"	"	7.5	7.2	"	21,360
11	"	"		"	"	1,000+	24—	6—	6—	20—	4—	6—	6—	277.6		277.6	145.0	144.	1.	"	"	7.0	7.8	"	64,080
12	"	3,700		"	"	1,380+	60—	18—	22—	16—	24—	18—	18—	267.2		267.2	148.9	132.2	16.7	"	"	8.0	7.8	"	
13	"	"		"	"	3,600+	104—	24—	66—	40—	48—	36—	50—	263.9		263.9	131.8	153.4		"	"	7.6	8.0	"	64,080
14	600	"		"	"	12,400+	460—	80—	100—	100—	140—	120—	140—	263.9		263.9	142.9	133.8	9 1	"	"	7.7	7.6	"	21,360
15	720	"		"	17	13,300+	400—	100—	140+	190+	120—	200—	160—	254.5		254.5	137.8	140.8		"	"	8.	8.0	"	45,390
16	"	3,300		"	18																				21,360
17	"	"		"	"	13,500+	260—	60—	64—	66—	100—	124—	80—	227.5		227.5	127.0	124.	3.	"	"	7.8	8.0	"	
18	"	"		"	"	15,300+	220—	170—	164—	180—	200—	168+	180—	227.8		227.8	119.1	110.8	8 3	"	"	7.6	8.2	"	64,080
19	720	"		"	"	11,700+	420—	100—	120—	140—	100—	186—	124—	217.8		217.8	124.8	124.	8.	"	"	8.	8.0	"	21,360
20	840	3,100		"	"	5,000+	160—	52—	44—	48—	50—	62—	78—	230.4		230.4	123.0	121.8	1.2	"	"	7.5	7.6	"	
21	"	"		"	"	5,020+	206—	48—	44—	44—	40—	50—	36—	249.3		249.3	121.6	109.2	12.4	"	"	7.6	8.0	"	45,390
22	"	3,000		"	"	6,800+	240—	80—	110—	84—	120—	96—	112—	248.0		248.0	129.3	117.0	12.3	"	"	7.6	7.8	"	"
23	"	"		"	"																				
24	"	"		400	"	4,200+	176—	38—	30—	28—	36—	26—	28—	266.		266.0	143.9	107.6	36.3	"	"	7.	2.2	"	21,360
25	"	"		300	"	3,100+	210—	24—	20—	24—	32—	26—	32—	268.		268.0	151.0	112.	39.0	"	"	8.	8.2	"	42,720
26	"	"		"	"	2,300+	160—	32—	18—	24—	28—	36—	28—												23,360
27	"	"		"	"	3,400+	196—	26—	30—	22—	28—	28—	32—	269.2		269.2	153.1	114.4	34.7	"	"	8.0	7.8	"	24,030
28	"	"		"	"	3,900+	224—	34—	26—	60—	58—	44—	36—	251.8		251.8	133.4	112.2	21.2	"	"	7.6	7.9	"	45,390
29	"	"		"	"	6,000+	236—	28—	30—	28—	64—	24—	20—	259.		259.	128.9	128.	9.	23	"	8.2	8.4	"	21,360
30	"	2,500		"	"									226.5		226.5	125 5	117.6	7.9	33	"	8.0	9.1	28	
31	"	"		"	"	13,800+	500+	220—	160—	240—	214—	264—	238+	191.8		191.8	121.6	108.0	13.6	40	"	9.7	8.3	60	40,050

Date	CHEMICALS					BACTERIA								ALKALINITY										
														Raw			Filtered			Color		Chlorine		Turbidity
	Fe	Ca	Al	Na	Hypo	Raw	Settled	Clear well	Lab. tap.	1	2	3	4	Total	N.C.	B.C.	T	N.C.	B.C.	Raw	Filt.	Raw	Filt.	Raw
4/1/13	840	2,300		300	19	30,800+	520—	294—	266—	380—	328—	280—	334—	164.5		164.5	100.6	102.6	2.6	56	21	8.9	10	110
2	"	"		"	"	72,000+	680—	52—	58—	150—	124—	166—	178—	153.5		153.5	77.9	76.8	1.1	54	21	9.2	9.9	250
3	"	2,200			"	86,000+	740+	196—	220—	320—	260—	324—	380—	149.7		149.7	78.3	79.6	1.3	54	21	9.3	9.8	250
4	"	"			"	69,500+	624—	262—	246—	300—	256—	320—	282—	145.9		145.9	72.5	72.2	.3	56	21	7.6	7.6	250
5	990	2,100			"	35,500+	600—	36—	24—	14—	24—	22—	14—	147.1		147.1	57.7	57.4	.3	46	16	10.	10	150
6	"	"			"									138.8		138.8	57.7	57.4	.3	46	16	9.8	9.9	140
7	"	"			"	9,200+	240—	14—	16—	8—	8—	6—	10—	133.5		133.5	50.6	52.4	1.8	46	16	9.8	9.9	150
8	"	2,000			"	9,800+	196—	6—	10—	4—	12—	8—	8—	139.0		139.0	58.3	56.8	1.5	46	16	10.	10.	140
9	"	"			"	12,000—	170—	6—	12—	14—	10—	6—	26—	150.8		150.8	56.2	53.0	3.2	40	14	10.	5.3	110
10	"	"			"	7,000+	100—	4—	8—	4—	16—	22—	20—	158.5		158.5	68.5	56.0	12.5	40	14	9.5	9.	90
11	"	1,900			"	8,600+	122—	22—	24—	8—	16—	30—	10—	149.0		149.0	60.4	58.4	2.	40	14	9.5	9.	70
12	"	"			"	3,550—	84—	4—	6—	2—	0—	4—	4—	143.6		143.6	57.8	56.4	1.4	40	14	9.2	8.9	60
13	"	"			"									154.7		154.7	62.2	56.4	5.8	33	12	10.	9.6	50
14	"	"			"	2,900+	60—	8—	6—	6—	2—	4—	4—	157.3		157.3	77.0	61.6	15.4	33	12	9.8	9.8	50
15	"	"			"	3,100+	40—	6—	8—	12—	2—	2—	4—	159.5		159.5	66.7	65.0	1.7	33	12	10.0	9.8	50
16	"	"			"	3,500+	48—	6—	8—	14—	6—	2—	6—	153.2		153.2	70.9	60.8	10.1	33	14	9.	9.	250
17	"	"			"	2,800+	28—	10—	10—	12—	10—	8—	6—	156.8		156.8	80.8	51.4	29.4	21	10	5.3	5.4	220
18	"	"			"	3,200+	68—	6—	10—	28—	26—	10—	10—	167.7		167.7	76.0	61.6	14.4	"	"	5.8	5.7	200
19	"	"			"	2,900+	24—	11—	8—	4—	4—	8—	2—	171.6		171.6	75.2	65.8	9.4	"	"	6.	6.	180
20	"	"			"									192.0		192.0	60.5	44.8	15.7	"	"	5.8	3.7	150
21	860	2,000			"	3,600—	140—	12—	12—	10—	22—	6—	6—	188.		188.0	71.0	49.4	21.6	"	"	6.7	6.8	110
22	"	"			"	2,700—	12—	8—	8—	6—	4—	8—	10—	198.		198.0	77.5	53.4	24.1	"	"	5.9	5.8	110
23	"	"			"	3,800—	128—	56—	49—	20—	10—	22—	18—	197.		197.0	80.5	59.0	21.5	"	"	6.9	7.0	110
24	"	"			"	4,750—	240—	180—	190—	90—	80—	70—	80—	196.		196.0	84.0	62.0	22.0	"	"	7.9	7.6	110
25	"	2,100			"	4,800—	220—	160—	180—	98—	76—	88—	90—	192.		192.0	80.3	80.6	21.7	"	"	9.4	9.0	90
26	"	"			"	3,800—	196—	100—	120—	82—	96—	62—	58—	199.7		199.7	80.2	60.0	20.2	"	"	9.4	9.0	90
27	"	"			"									198.		198.0	67.0	60.0	7.0	"	"	8.9	8.9	90
28	"	"			"	5,400—	240—	120—	98—	72—	60—	84—	70—	203.		203.0	79.	64.8	14.4	"	"	9.2	9.0	85
29	"	"			"	3,100—	70—	68—	56—	42—	38—	50—	46—	212.1		212.1	102.6	77.8	24.8	"	"	8.	7.8	80
30	"	"			"	1,600—	32—	24—	24—	18—	24—	16—	18—	224.		224.	107.6	78.6	29.0	"	"	7.2	7.4	75

Date	Wash Water
4/1/13	21,360
2	"
3	45,390
4	
5	40,720
6	21,360
7	
8	21,360
9	40,050
10	
11	21,360
12	
13	45,390
14	21,360
15	"
16	
17	61,410
18	16,020
19	21,360
20	
21	
22	
23	
24	21,360
25	"
26	
27	
28	42,720
29	42,720
30	


FARGO NORTH DAKOTA
Pipe Line Capacity
Curve 'B' Nat Board Fire Underwriters Standard
" 'A' Kuichling's Standard 1897
Assumptions
Population
10000
100000
300000
Per Capita Cons.
50 Gallons
80 "
100 "
1912
To accompany Report of
City Engineer
B
A
Percent of Total Capacity
Required for Fire Protection
Population in Thousands
0 10 20 30 40 50 60 70 80 90 100
0 20 40 60 80 100 120 140 160 180 200


10
CITY OF FARGO
1913
Cost of furnishing water per 1000 gallons
Effective
City Engr
Labor
Coal
Interest and Sinking Fund $65000
60000
Chemicals
Distribution mains
Plant Depreciation
Interest on $90000
Accounting Maintainance
Insurance
CENTS PER 1000 GALLONS
MILLION GALLONS PER YEAR
1000
900
800
700
600
500
400
300


11
CITY OF FARGO
1913
Cost of furnishing water to city
These cost curves are based on data that
was available March 1st 1913
To accompany report of
Alfred Lee City Engineer
and interest on $3000,000 @ 4%
and interest and sinking fund on $1000,000
and interest and sinking fund on $650,000
and distribution
and insurance
and depreciation
and maintenance
and accounting
Labor, coal and chemicals
Labor and coal
Labor
MILLION GALLONS PER YEAR
CENTS PER 1000 GALLONS
1000
900
800
700
600
500
400
300
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

DISCUSSION

Mr. C. Arthur Brown: A very interesting thing about this plant, so far as the speaker is aware, has not been developed at any plant in the United States, namely, the use of iron without the use of lime for considerable periods of time without any other agent, simply adding the iron to the water. It would seem that the action of the mixing chamber must play a certain part in its ability to perform that work without the use of caustic.

President Gwinn: Is that due to the perfect mixing that has been secured?

Mr. C. Arthur Brown: Yes, and the fact that the water is subjected to a pressure of 20 feet head which is alternately released and applied upon every cycle, upward and downward movement. It makes about fifty-seven of these in its passage through the mixing chamber.

THE CLOSE RELATION EXISTING BETWEEN THE PHYSIOLOGICAL RECORDS AND THE CHARACTER OF THE POTABLE WATER SUPPLY

By L. J. Le Conte, C. E.

It is universally conceded that moderately hard waters are decidedly advantageous for city water supply, where wholesomeness alone is considered. The human system needs lime in physical development. Scientific efforts to prove this by *Death Rate Records* develop results which are unreliable and the matter unfortunately was dropped.

The question at once arises, why did they not extend their investigations to include the *Physiological features as well?* If they had done this the results would have shown, overwhelmingly, that all the communities supplied with limestone waters invariably develop the largest and strongest men and women to be found anywhere. This fact is universally true all over the entire Appalachian region. The particular states of the Union studied are Kentucky, Tennessee, Georgia, North and South Carolina. The physical development not only of the human family, but also of the horses, mules and cattle of all kinds shows conclusively larger, more healthy and stronger specimens in every way.

As you go down hill from the mountains towards the seacoast the physical development of the men and women grow markedly less and less until you reach the seacoast where they are the smallest and physically defective in every respect.

While visiting the southwestern corner of North Carolina I ran into a colony of Charlestonians, who spend their summers there regularly. In discussing the matter they told me that the people on the seacoast got their horses and cattle, originally, from Kentucky and Tennessee, and that in the natural course of events each generation grew less and less in size and strength until finally nothing was left of them except the mane and tail—we then replenish our stock. Exactly the same physical phenomenon is also observed

in the human family, each successive generation growing smaller and weaker, unless some corrective is resorted to which consists in spending every summer in the limestone water mountains. This precaution is particularly desirable and necessary for the development of growing children who are kept in the mountains as long as possible. The poorer classes, however, who cannot afford such expensive excursions of course have to stand the consequences, with the result that the community, as a whole, is largely far below the standard for size and strength. This potent fact was well developed in the reports of the recruiting officers during the late war of 1861–1865. These reports show conclusively, without any shadow of doubt, that the biggest and strongest men, horses and mules all came from the mountainous limestone countries, invariably.

Another most convincing case is that of the city of Manchester in England. Back in the early days she used to furnish just as many men for recruits in the British Army as any other district in the United Kingdom. Since the introduction of a *soft water supply* the number of recruits has steadily grown less and less, although the city itself was growing rapidly, until now practically all the recruits are rejected as not coming up to army requirements and in other words the men were *physically unfit for the British Military Service*. What could be more thoroughly convincing than this?

About 1880 the Swiss and French doctors discovered the important fact that "goitre" was a disease due to *soluble silica* in the potable waters. Now in 1913 the Italian doctors announce the discovery that the *universal malady,* known as "Pellagra," which carries off 50,000 persons per annum in Italy, is due to the same trouble—soluble silica in the drinking water. They state that the true remedy for this terrible malady is a dose of carbonate of lime in the drinking water.

Here we have strong scientific evidence of the sanitary value of hard waters as affecting the public health. This is what we have all been waiting for and it has now arrived. In view of the fact that a number of softening plants are now being projected to seriously reduce the degree of hardness of some potable waters it is thought highly proper to call the public attention to the possible dangers that may follow if carried too far.

This paper is written with the view of giving timely warning of the danger of softening waters too much and thus developing most serious results, as anyone at all conversant with the facts can readily see and understand.

Let it be clearly understood that in designing softening plants you are in point of fact meddling with the very backbone of wholesome potable waters, and such proceedings should be carefully undertaken with the greatest caution and with the most intelligent supervision; otherwise the most serious sanitary results will certainly follow.

DISCUSSION

Mr. George W. Fuller (by letter): Mr. LeConte's proposition appears to involve a mixed question of eugenics, general sanitation, and public and personal hygiene. His conclusions are not generally recognized, and it is not unlikely that his premises deal with such a wide range of factors and opinions, that data could be selected which would clearly point to a conclusion just the opposite from that which he states.

It is not probable that water softening plants will ever be called to account for any injurious effects on the health of the consumers, due to reduction of hardness. Owing to the natural solubility of the salts of lime and magnesia, it is absolutely impossible to make a hard water through the application of lime and soda approach in its softness that of many of the natural waters found along the Atlantic seaboard. Some water softening plants are designed with a view to reducing excessive hardness only to about 120 parts per million, equal to that shown by the waters of the Great Lakes. There are no cases where waters are softened to less than a residual hardness of about 75 parts per million. To attempt to reduce the hardness still lower not only involves needless expense, but presents operating difficulties that are hard, if not impossible, to manage, unless the period of contact of the lime with the water is very large, or unless there should be devised some means of freeing softened water from large amounts of caustic alkalinity. These complications of course arise much more in winter, when the speed of reaction is far slower than at summer temperatures.

It is safe to say that the misgivings of the author are not likely to occur with respect to the results of water softening operations on a large scale.

Mr. William Miller Booth (by letter): The subject interests the writer who has tried for ten years to obtain authentic informa-

tion relating to the physiological effect of hard and soft water when used for drinking purposes.

The experience of those who travel over extended areas easily proves the importance of the water supply in the daily economy. Old people object to a change in this particular and often suffer greatly physically.

Broadly speaking there are three distinct types of water used in the United States: soft water in and adjoining igneous rock areas of the east, hard water over sedimentary rock areas of the middle west and south, and alkaline waters on the western plains and plateaus.

New England coast cities, New York and Philadelphia use very soft water, hardness 50 parts per million or under. The very populous area between Albany and Chicago mainly derives its supply from limestone and shale, producing a water of medium hardness. Transmississippi waters are usually hard and many contain carbonates of the alkalies.

If hard water areas produce a healthier man than soft, a collection of statistics from such areas over a sufficient term of years ought to prove or disprove the claim.

The writer is personally familiar with more than 200 underground water supplies. These are pretty generally located in New York state. Mineral analyses often show the presence of barium and strontium, always of iron, calcium and magnesium. Such waters are usually hard, varying from 100 to 1600 parts per million. The minerals found are bicarbonate of calcium, bicarbonate of magnesium, sulphate of lime, sulphate of magnesium, sulphate of soda, chlorides of soda, calcium and magnesium.

Whatever may be the facts, there is general prejudice against hard water over this area and physicians advise the use of distilled water in rheumatic cases and kidney trouble. Experience has proved the value of this simple remedy.

The physiological effect of magnesium and sodium sulphates is well known. Waters that contain these salts are sure to have an influence on the body. The citizens of Medina, Ohio, drank water in 1906 that contained 220 grains of sulphate of soda per gallon. Visitors were unable to use this.

Chlorides of calcium and magnesium are powerful hygroscopic chemicals. The United States Dispensatory is not definite regarding the physiological action of either of these salts. They are found in well known and popular European waters.

Carbonates of calcium and magnesium are regularly employed in medicine. Gypsum is not administered medicinally internally. Physicians avoid waters containing this mineral. A well known water, prescribed for rheumatism, is saturated with this salt, containing 1500 parts per million. Its inertness gives one a bad impression of its action in the body.

In addition to these salts, ground waters carry traces of many minerals, the accumulation of which in the system may result in severe disorder. Barium and lead belong to this group, also common salt. The quantity of this is usually negligible from a physiological standpoint.

The gradual change from hard, underground waters, minerally contaminated, to soft, reservoir supplies will be generally beneficial. An eminent sanitarian was asked what a man should eat to keep his system in the best trim. He answered, "what your appetite demands." If the body needs lime, magnesium, soda or potash, it will get this through the food, if not through the water supply.

The general use of distilled water in the navy, of soft water in Glasgow, Scotland, and of rain water in many isolated localities will prove its value or detrimental qualities. We can then draw conclusions.

Artificially softened water has been used for drinking purposes for many years in the chalk areas of England. The Southampton plant was recently enlarged. All reports that the speaker has been able to obtain are favorable for the use of water softened by the lime-soda process. The product should be slightly alkaline from the residual and soluble carbonates of calcium, and should contain no free lime or soda. The sulphate of soda remaining after gypsum water is treated can certainly not be more injurious than gypsum itself. The speaker has used softened water eight years for food purposes and with no complaints. For household and manufacturing purposes every municipal supply should be softened to a hardness not exceeding 85 parts per million. This in the writer's opinion will be quite generally done. Waters of the Great Lakes particularly would be very much improved from a mineral standpoint, no regard being paid to the vast improvement that this process makes bacteriologically.

METHOD OF CLEANING A RESERVOIR

By Alvin Bugbee

The reservoir of which this paper deals is a storage basin for the city of Trenton, New Jersey. The population supplied is about 120,000; consumption about 20,000,000 gallons every 24 hours.

This reservoir was built without any dividing wall, and has a capacity of 120,000,000 gallons. It is about 45 feet deep and is elliptical in shape. There are two 48-inch outlets for supply and one 48-inch intake, and there are two pipe lines from the pumping station; a 48-inch lock bar steel line and a 36-inch cast iron main. These two lines are connected by a Y branch at the base of bank at reservoir to the 48-inch intake, each line having a valve near this connection.

Before pumping filtered water into the reservoir it is, of course, advisable to remove the sediment from the bottom. There have been no outlets left in the bottom, except the outlets which supply the city with water. One of these outlets has an elevation of 3 feet from the bottom, and the other 12 feet from the bottom.

In order to supply the city while the basin is being cleaned it will be necessary to pump direct into the mains. This is the method that has been decided on, and requires the ascending mains all to be connected with the supply mains. The supply mains at the reservoir consist of two 30-inch lines and a 36-inch line, which are connected in the gate house to the 48-inch lines from the reservoir.

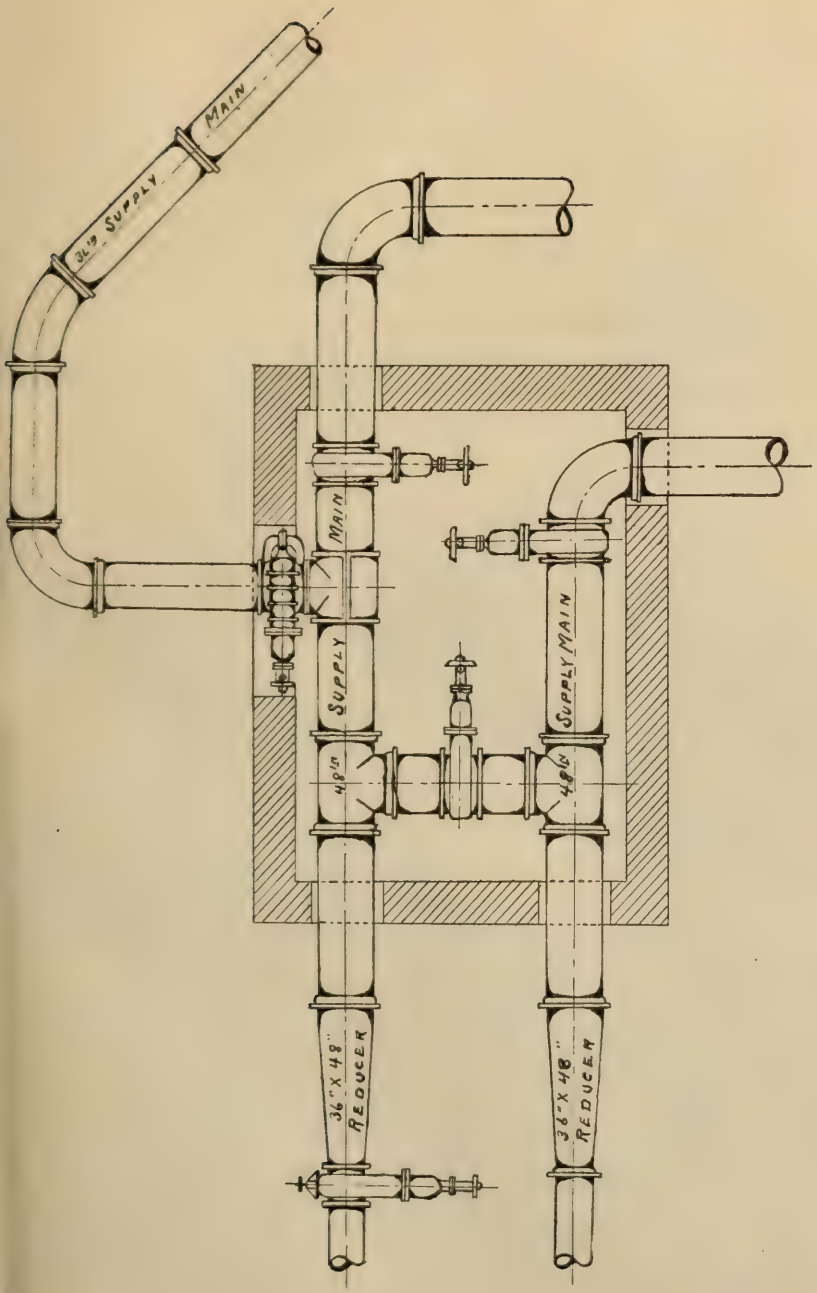
Referring to the plan accompanying this article it will be seen that a number of new valves have been placed on the main lines. There is a valve shown just outside of the gate house on the 36-inch supply. This valve had to be placed at this point to prevent the water from passing back through the gate house and following out the same pipe that is used to empty the reservoir.

It will be evident by consulting the plan that on closing the valve on the 36-inch line at point D the water from the reservoir will be carried through the 20-inch line down to the creek. The outlet pipe is three feet from the bottom of the reservoir and it will be necessary to pump the remaining water into this outlet. The plan

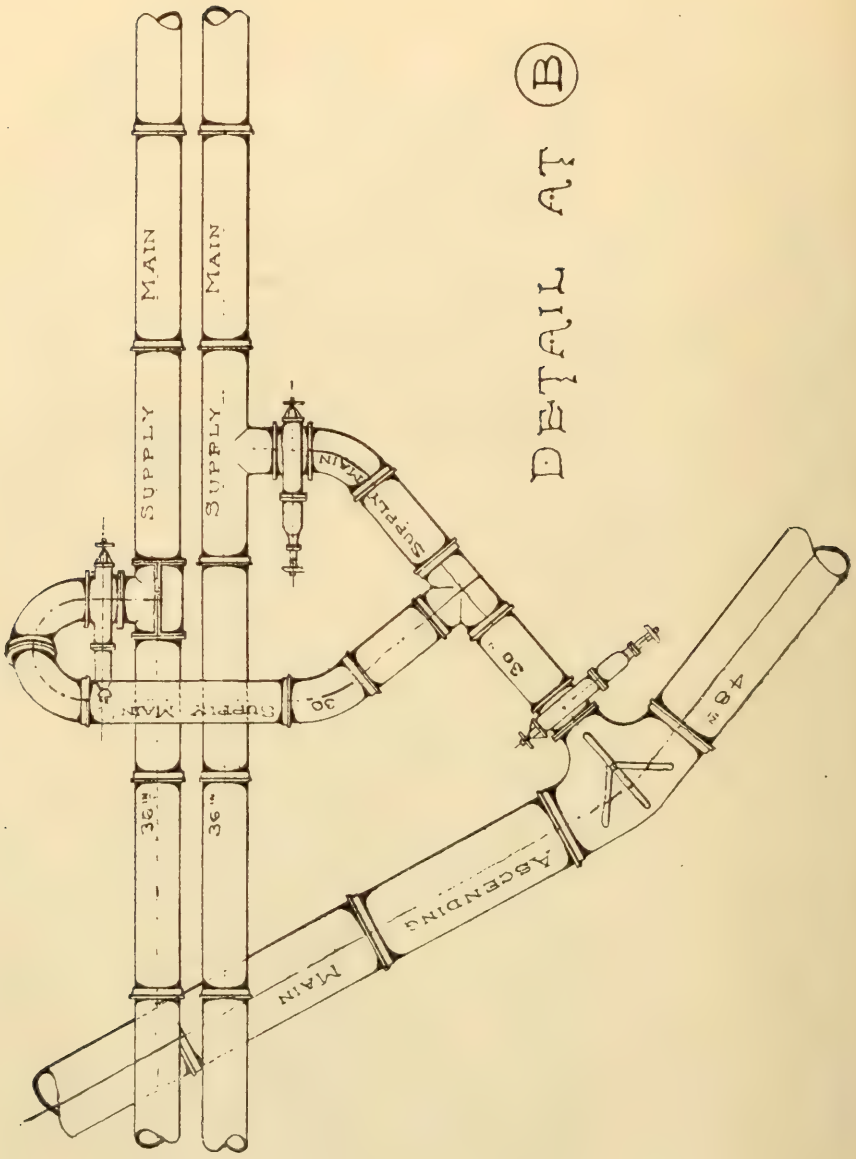
contemplated is to use 4-4-inch electrically driven centrifugal pumps. These pumps will be mounted on a raft before the water is lowered. The amount of water to be pumped will be about 3,000,000 gallons, and the sediment will be kept in agitation and pumped out as sludge.

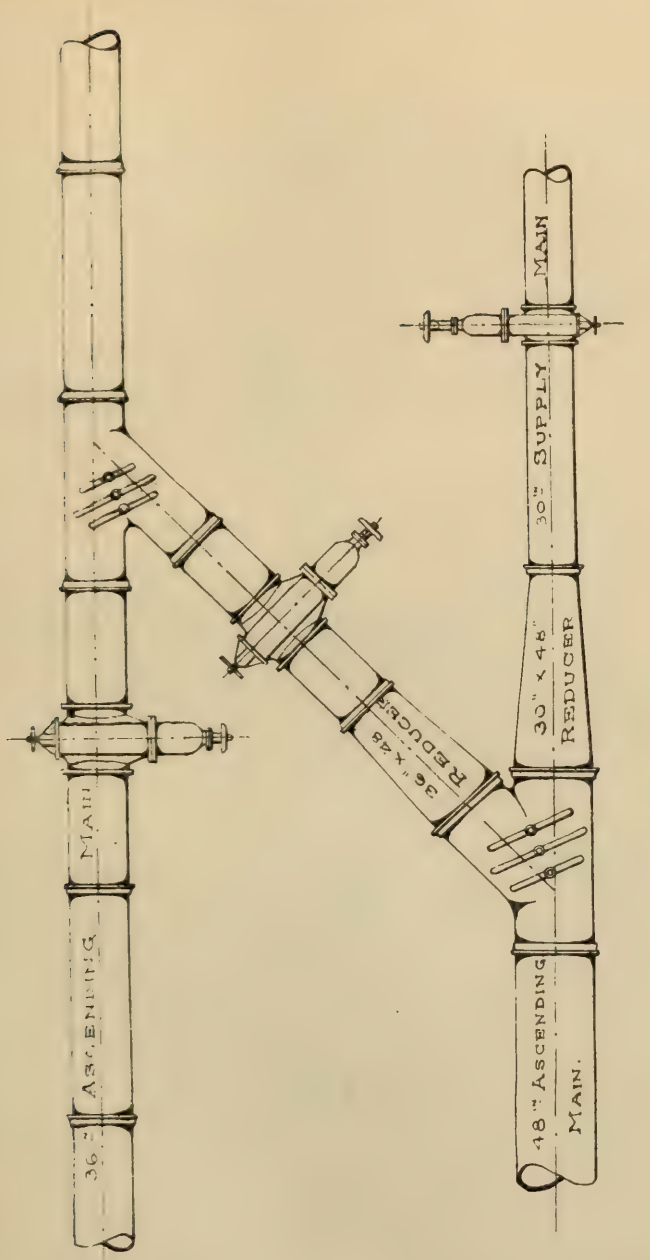
These centrifugal pumps are estimated to pump about 7,500 gallons each per hour or 30,000 gallons per hour combined, therefore, it will require about 100 hours to empty the reservoir after the water is down to a depth of 3 feet. We contemplate that it will take 5 days working day and night, as no doubt there will probably be some slight delays. In putting in the new valves spoken of previously, one of the supply lines will be shut off at a time. This will be done between Saturday noon and Monday morning when the consumption is at its lowest. In order to avoid the water hammer from the pumps the valves at point C which control the water in the mains leading into the reservoir will be left open, so that in case the pumpage is not consumed regularly from hour to hour, the slight excess will be discharged into the reservoir, thus avoiding the danger of straining any of the joints, stalling or overloading the pumps. The pipe entering the reservoir extends 10 feet above the high-water line so that there will be considerable leeway before the water will discharge into the reservoir, and will insure a pressure throughout the city equal to the normal.

CREEK
SHABAKUNK
MAIN
PARKWAY
AVENUE
36"in SUPPLY MAIN
To CITY
STREET
PROSPECT
RESERVOIR
OUTLETS
MAINS
GATE HOUSE
PENNINGTON AVENUE
TWO 36"in SUPPLY MAINS

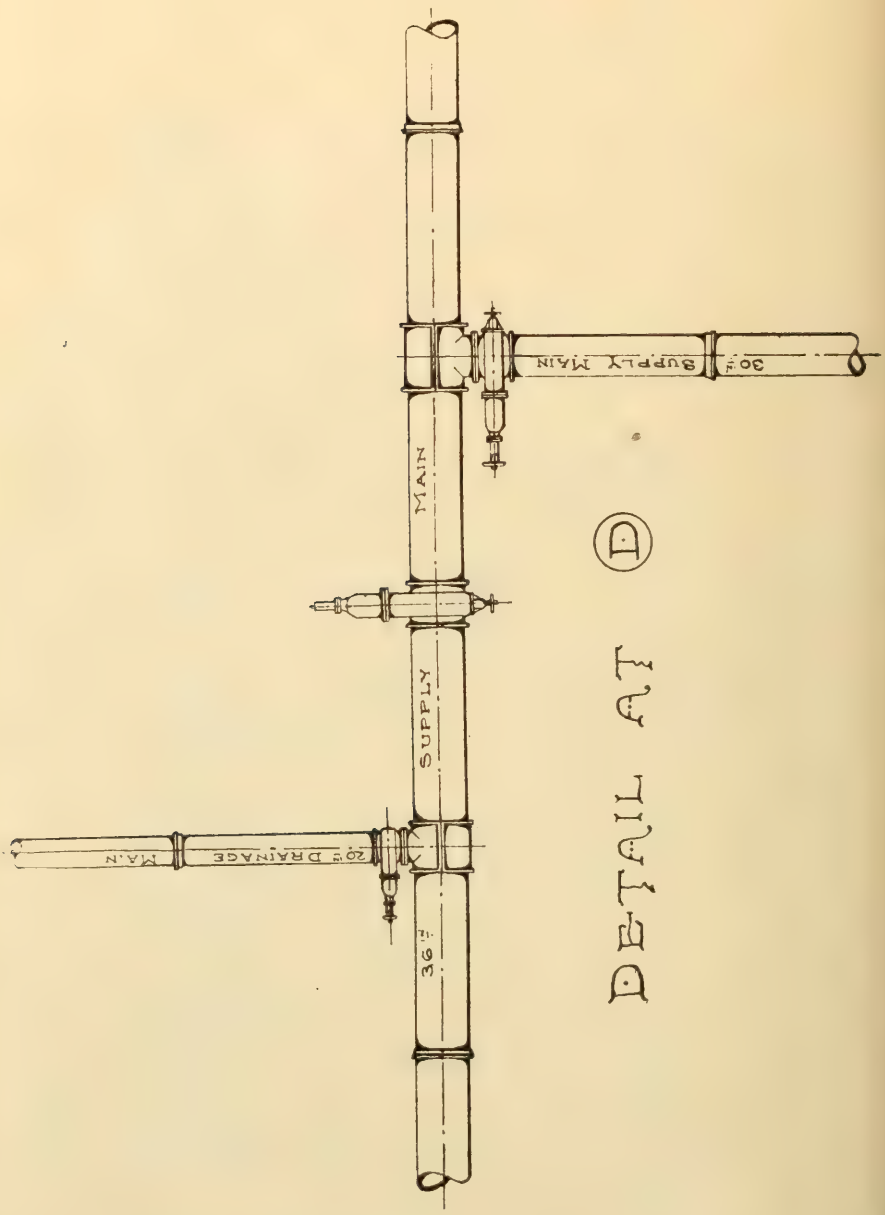

36"ø SUPPLY MAIN
SUPPLY MAIN
48"ø
SUPPLY MAIN
48"ø
36"X 48" REDUCER
36"X 48" REDUCER

DETAIL AT (A)


DETAIL AT (B)
MAIN
SUPPLY
MAIN
SUPPLY
SUPPLY MAIN
30"
30"
48"
36"
36"
ASCENDING
MAIN


36" ASCENDING MAIN
36" x 48" REDUCER
30" SUPPLY MAIN
30" x 48" REDUCER
48" ASCENDING MAIN.

DETAIL AT (C)



DETAIL AT (D)

New Croton Dam

MASONRY DAMS[1]

By Edward Wegmann

The construction of masonry dams dates from about the middle of the sixteenth century, when walls of masonry were constructed

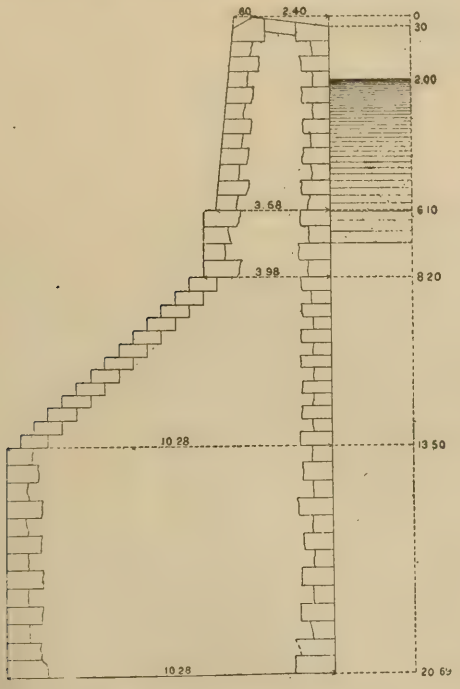


Fig. 1. Almanza Dam

across some of the streams in the southern part of Spain, in order to form large reservoirs for irrigation. The oldest of these structures, of which any records exist, is the Almanza Dam (Fig. 1), situated in the province of Albacete, near the town of Almanza. The exact date of its construction is unknown, but we learn from some old documents that the reservoir formed by this

[1] An address illustrated by lantern slides, given by the author at the annual convention in Minneapolis, June 24, 1913.

dam was in use prior to 1586. For the first 48 feet above the foundation, the dam is built curved in plan, convex upstream, to a

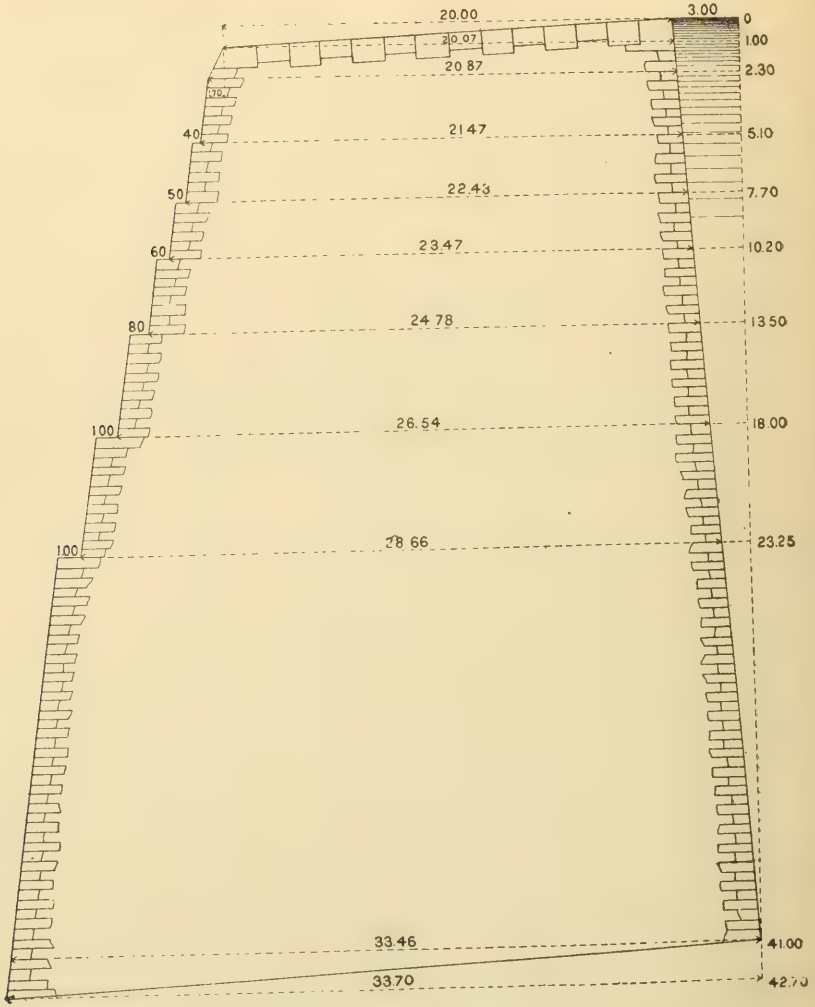


Fig. 2. Alicante Dam

radius of about 86 feet. The part of the wall above this level is supposed to have been built at a later period. Instead of being curved, the center line of its plan forms a broken line, 292 feet long. The maximum height of the dam is about 68 feet. An overflow, about 39 feet long and $6\frac{1}{2}$ feet deep, was made by excavating the

rock on one side of the dam. Water is drawn from the reservoir through a gallery, about 3.28 by 3.28 feet in cross section, which is constructed through the lower portion of the dam and is controlled at its downstream end by means of a bronze gate. In order to prevent the gallery from becoming filled with silt, the gate is kept partially open during floods.

Owing to the steep declivity of the beds of the streams in southern Spain, where the first masonry dams were built, and to violent storms, the reservoirs formed by these dams would become filled with silt in a few years, if some special means had not been provided to get rid of the silt. This is accomplished by scouring galleries, constructed through the masonry of the dams, at the bottom of the reservoirs. In the Almanza Dam this gallery is about 4.3 feet wide by 5 feet high. Its upstream end is closed by a timber bulkhead which has to be removed by hand, when the reservoir is to be scoured out. In the description of the next dam, which has a larger scouring gallery, we shall describe more fully how this operation is performed.

The dam is constructed of rubble masonry faced with cut stone. While not properly proportioned according to modern theories, it is an interesting fact that the masonry of this old structure sustains safely a maximum pressure of about 14 tons per square foot.

The Alicante Dam (Fig. 2), constructed in 1579 to 1594, to supply water for irrigating the arid region of Alicante, is the highest masonry dam in southern Spain. It is supposed to have been built by Herreras, the famous architect of the Escurial palace. The dam closes a narrow gorge, formed of hard limestone, which is only 30 feet wide at the bottom and 190 feet wide at the crest of the dam. The sides of the gorge are almost perpendicular. The dam is built of rubble masonry, faced with large cut stone. Its greatest height at the upstream side is 135 feet. In plan the wall is curved, convex upstream, to a radius 351 feet at the crest.

Water is taken from the reservoir through a well, 2.62 feet in diameter, constructed in the dam at its upstream face. The well is provided with a number of inlet openings, placed at different levels. From the foot of the well a horizontal gallery, constructed in the dam, parallel with its upstream face, conveys the water to a small outlet tunnel, about 2 feet wide by $5\frac{1}{2}$ feet high, which discharges the water into the stream below the dam. A bronze sluice gate, placed at the downstream end and operated by means of a

handwheel and gearing, regulates the quantity of water drawn from the reservoir.

The silt deposited in the reservoir has to be removed about once in every four years, in which time it has filled up the reservoir to a height of 39 to 52 feet. The silt is scoured out through a gallery, as in the case of the Almanza Dam, but in the Alicante Dam this gallery was made about 6 feet wide by 9 feet high at its upstream end and gradually enlarged, so as to be about 13 feet wide by 19 feet high at the downstream end. The inlet to the gallery is closed by a timber bulkhead, consisting of two courses of 12 x 12 inch timber, the pieces of one course being placed vertically, while those of the other are laid horizontally. The ends of each timber are placed in grooves, cut in the masonry, and the joints between the timbers are calked so as to make them watertight. Inclined braces are put in the gallery against the bulkhead to give it additional strength. In the course of four years the silt deposited in the reservoir acquires such consistency, that no difficulty is usually experienced in removing the timber bulkhead, when the reservoir is to be scoured out. In fact the workmen have often to punch holes through the silt with a long bar, from the top of the dam, to start a current through the gallery. Occasionally, however, the water forces the silt into the gallery, before the men who are removing the bulkhead have time to escape. Accidents of this character are, however, said to be rare.

No wasteweir was provided originally for the Alicante Dam, the water passing over the crest of the wall in case of floods. As it was feared that the downstream face of the dam might be injured by the water flowing over the dam, a wasteweir was constructed in 1607, at one side of the dam. During a great flood in 1792 water to a depth of 8.2 feet passed over the top of the dam and fell in perfect cascades on the downstream face. As the masonry was not damaged by this severe test, the wasteweir was closed and the dam left to discharge flood water over its crest as originally intended.

The Puentes Dam (Fig. 3), built in 1785 to 1791, was considered to be one of the great achievements of the reigns of Charles III and Charles IV of Spain. It was constructed a short distance below the place where three streams unite to form the Guadalantin River. The dam has a maximum height of 164 feet above the foundation and a length of 925 feet on the crest. The plan was made polygonal, convex upstream, and the wall was built of rubble and faced with

cutstones. It was finished by a magnificent parapet upon which large statues of the two kings, mentioned above, were placed.

An arched scouring gallery, about 22 feet wide by 25 feet high, was constructed through the dam. It was divided at its upstream

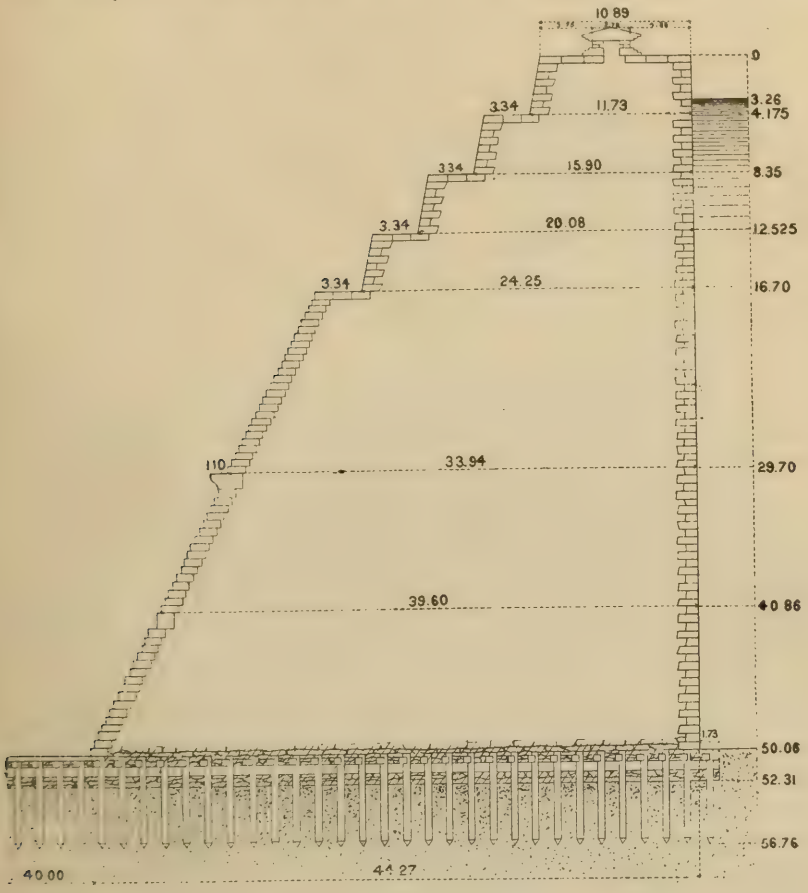


FIG. 3 THE PUENTES DAM

end by a central pier into two channels, in order to reduce the span of the beams in the bulkhead. Water is taken from the reservoirs through two wells, each continued through the dam by a horizontal gallery, 5.4 feet wide by 6.4 feet high. These galleries were placed at different levels, one being about 100 feet below the crest of the dam, while the other is near the base of the dam.

According to the original plans, the dam was to be founded entirely on rock. In excavating for the foundation, a deep pocket of earth was encountered at the center of the valley, where the scouring gallery and one of the outlet passages were to be located. In order to save expense, it was decided to build the dam at this place on a timber grillage, supported by piles, and to continue the grillage, as an apron, for about 131 feet downstream from the dam, to prevent any undermining by water coming from the scouring gallery or outlet channel. The pile foundation was built very securely and stood safely for eleven years, during which period the depth of water in the reservoir did not exceed 82 feet. When, however, on April 30, 1802, the water was allowed to rise to an elevation of 154 feet above the base of the dam, the pile foundation was pushed out by the great pressure in the reservoir and the dam was ruptured. The following account of the failure of the dam was given by an eye witness:

"About half past two on the afternoon of the 30th of April, 1802, it was noticed that on the downstream side of the dam, towards the apron, water of an exceedingly red color was issuing in great quantities in bubbles, extending in the shape of a palm tree. About three o'clock there was an explosion in the discharge wells that were built in the dam from top to bottom, and at the same time the water escaping at the downstream side increased in volume. In a short time a second explosion was heard, and, enveloped by an enormous mass of water, the piles and timbers which formed the pile work of the foundation and of the apron were forced upwards.

"Immediately afterwards a new explosion occurred, and the two big gates that closed the scouring gallery, and also the intermediate pier, fell in. At the same instant a mountain of water escaped in the form of an arc. It looked frightful, and had a red color, caused either by the mud with which it was charged, or by the reflection of the sun. The volume of water which escaped was so considerable that the reservoir was emptied in the space of one hour."

The failure of the Puentes Dam caused the loss of 608 lives and of property amounting to more than a million dollars in value. The ruptured part of the dam was not rebuilt for many years but the gap made in the dam was finally closed and the reservoir was restored to use.

A number of other masonry dams have been built in Spain. Those whose height exceeds 100 feet are mentioned in the table

on page 559. Among the most important of these structures are the following:

The Villar Dam was constructed in 1870–1878 across the Lozoya River to store water for the supply of Madrid. Its greatest height is about 170 feet and the length on top is 546 feet. In plan the dam was curved to a radius of 440 feet.

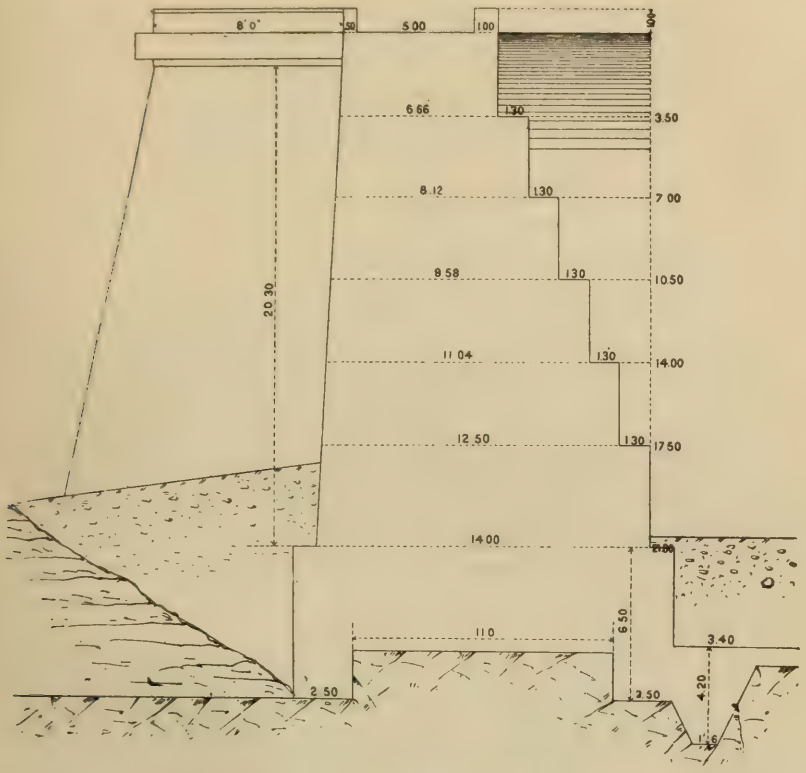


FIG. 4. GROS BOIS DAM

The Two Hijar Dams were built in 1880 on the Martin River, about two miles from the City of Hijar, in order to form two large reservoirs for irrigation purposes. The dams have similar dimensions, each having a maximum height of about 140 feet and a length on the crest of about 240 feet.

At the present time an American firm has undertaken to build some masonry dams in Spain in connection with irrigation projects. One of these walls is to have a height of over 300 feet.

France ranks next to Spain in the construction of early masonry dams. At first they consisted of comparatively low walls, built in connection with canals. One of the principal of these structures is the Gros Bois Dam (Fig. 4) built in 1830 to 1838 on the Brenne River, to form a reservoir for feeding the canal of Bourgogne. It has a maximum height of 93 feet above the foundation and a length of 1805 feet on the crest. The stratum on which this dam was founded consists of argillaceous rock, having little hardness. When the reservoir had been filled to a depth of 13 feet, a serious leak occurred under the base of the dam. The reservoir was emptied and the crevices in the rock, through which the water escaped, were closed with masonry or grout. The reservoir was then filled to a depth of about 57 feet. With the pressure due to this head of water the dam, which was built straight in plan, deflected a few centimeters, but it returned practically to its original position, when the reservoir was emptied, as the deflection was due to the elasticity of the masonry. In addition to this motion, the dam slid about 0.15 feet downstream. Several new leaks occurred at this time in the rock foundation and were stopped by grouting, etc. In order to strengthen the dam and to prevent all further motion, seven counterforts were built in 1843 against the downstream face of the wall. With this reinforcement the dam stood successfully for over fifty years. In 1896, it was deemed, however, advisable to relieve the dam of some of the pressure to which it was subjected by building an earthen dam, 57 feet high, about 800 feet below the masonry dam, thus backing water against the latter and relieving it of part of the pressure it had to sustain.

The early Spanish dams are all curved upstream in plan to secure additional strength by making the wall act as a horizontal arch. In all of these structures, however, the masonry has sufficient strength to resist the pressure of the water by its weight alone, and the curving of the plan adds simply additional safety to the dams. In France all masonry dams were built straight in plan until 1843, when the dam described below was constructed.

The Zola Dam (Fig. 5), built in 1843, to form a reservoir for supplying the city of Aix, France, is the first dam in which the resistance of the wall to the pressure of the water was made to depend entirely upon the dam's acting as a horizontal arch. The profile of the dam is so thin that the "line of pressure" for reservoir full, falls about 11.5 feet outside of the base of the wall. The structure would, therefore, inevitably be turned over by the water pressure

if it had not been arched in plan. For a maximum height of 120 feet above the foundation, the dam has only a thickness of 42 feet at the base. It is 205 feet long on top and the radius of the crest is 158 feet.

None of the early masonry dams were built according to correct designs. Most of them are unnecessarily thick at the top and some of these dams would be improved in strength if they were turned around, so as to place their upstream faces downstream. The

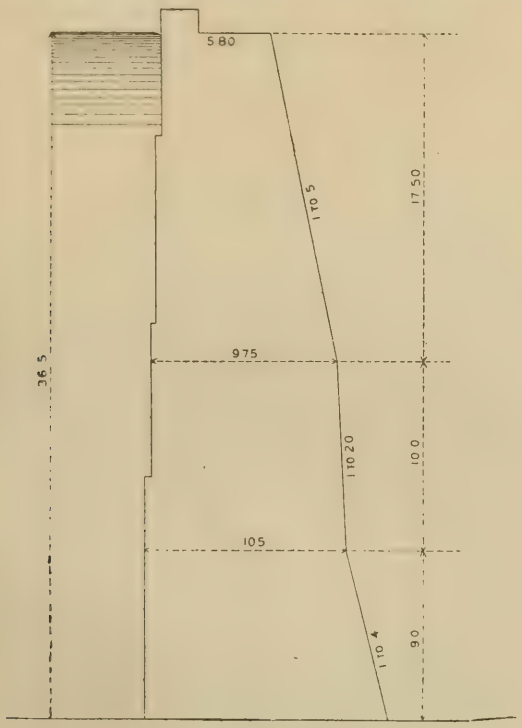


FIG. 5. THE ZOLA DAM

first correct theory of the proper way of designing the profile of a masonry dam was advanced in 1853 by de Sazilly, a French engineer. Delocre, Professor Rankin and other engineers modified and improved the principles laid down by de Sazilly. We shall consider their theories later, in a general manner.

Since de Sazilly published in a memoir in the Annales des Ponts et Chaussées the principles that should be followed in designing the profile of a masonry dam, all important structures of this kind have

been built according to rational plans. The first dam built with a correct profile is the celebrated Furens Dam, described below.

The Furens Dam (Fig. 6). About the middle of the last century the French government began to build a number of large reservoirs,

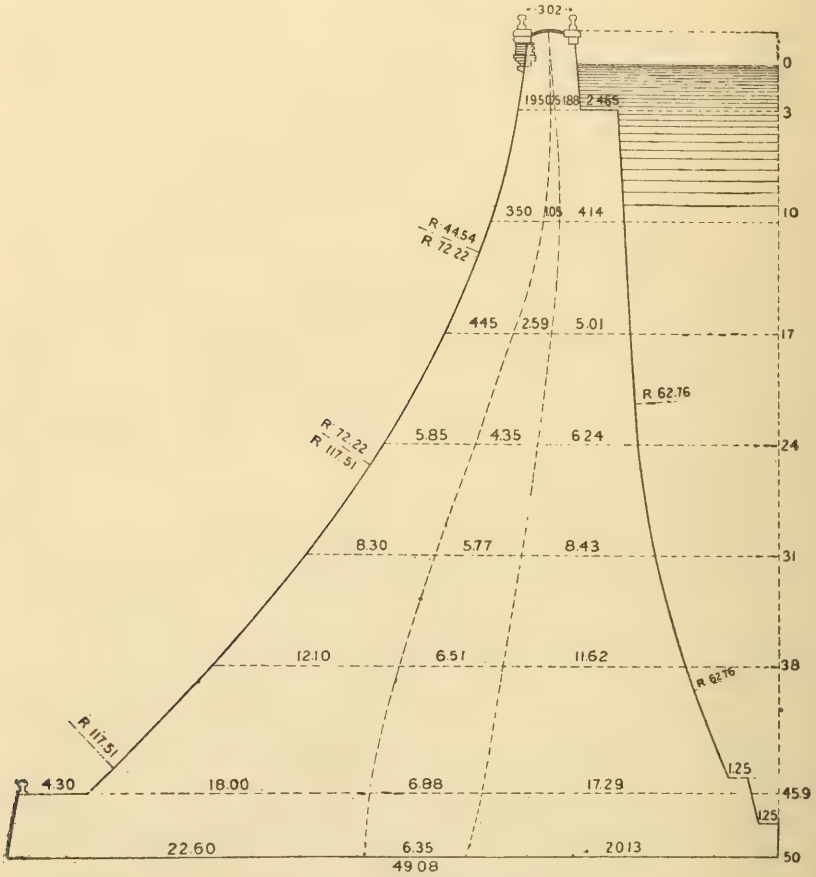
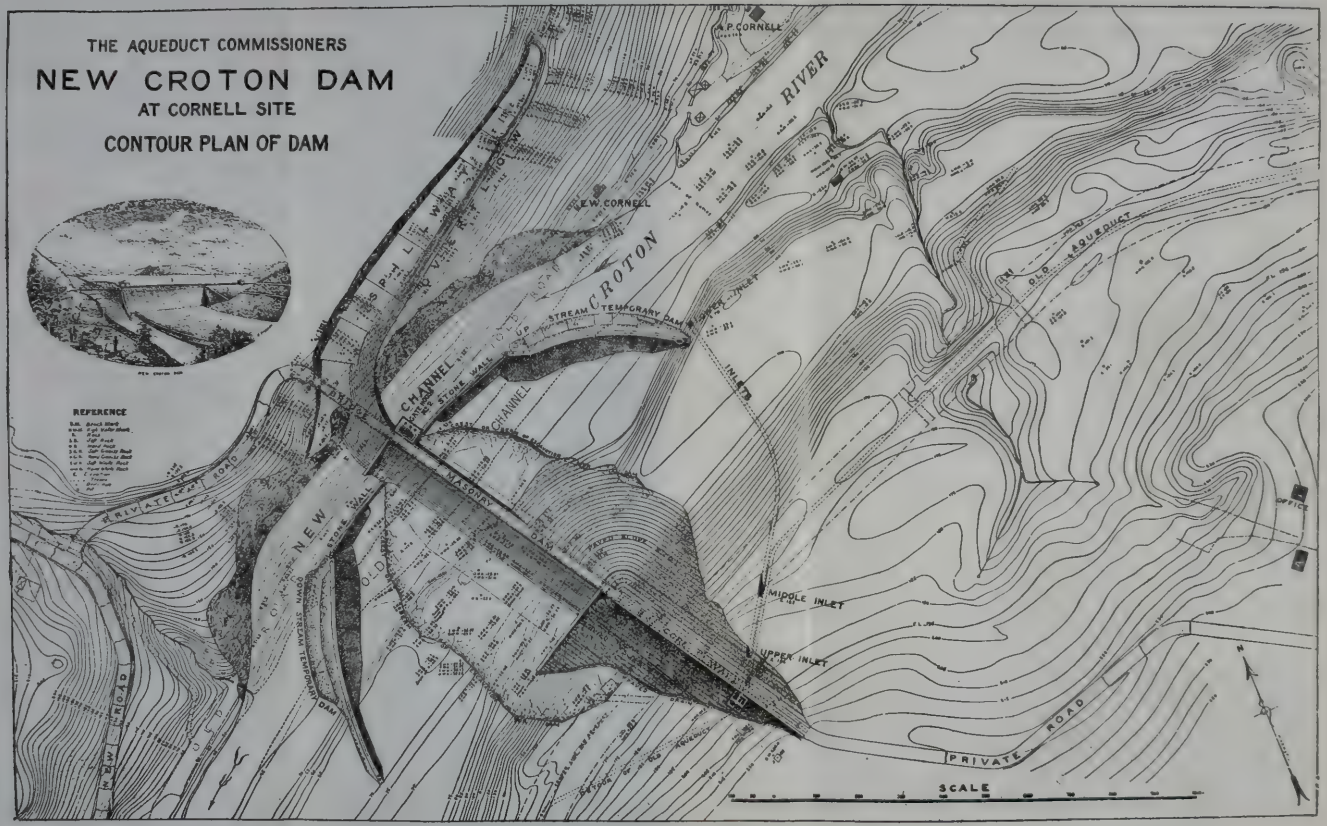
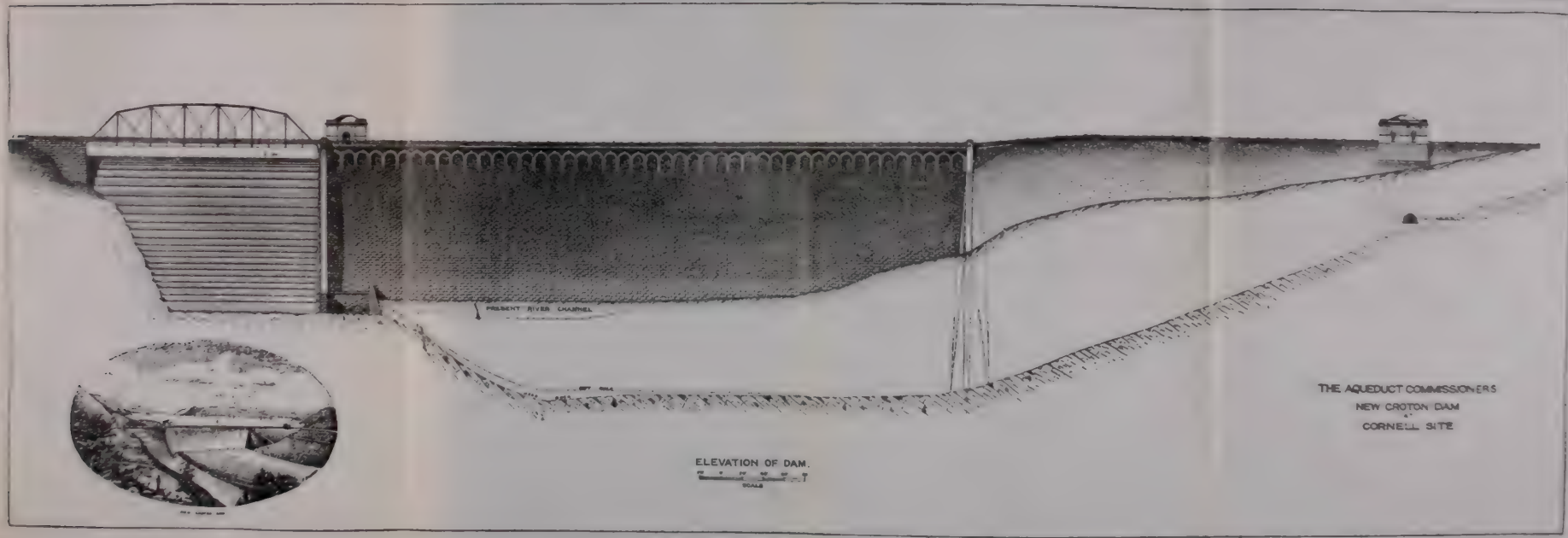


Fig. 6. The Furens Dam

to prevent inundations caused by large rivers during periods of flood. These reservoirs were to regulate the flow of the streams, storing the excess of water during floods for seasons of droughts. The first work of this kind undertaken was a large reservoir near Saint Etienne. It was formed by constructing a masonry dam, about 170 feet high, across the Furens River at a narrow gorge, known as "Gouffre d'Enfer." The profile of the dam was based


THE AQUEDUCT COMMISSIONERS
NEW CROTON DAM
AT CORNELL SITE
CONTOUR PLAN OF DAM
REFERENCE
A.P. CORNELL
E.W. CORNELL
CROTON RIVER
CROTON STREAM
TEMPORARY DAM
CHANNEL
STONE WALL
MASONRY DAM
OLD AQUEDUCT
INLET
MIDDLE INLET
UPPER INLET
OFFICE
PRIVATE ROAD
NEW CROTON ROAD
OLD CROTON ROAD
SCALE
N


PRESENT RIVER CHANNEL
ELEVATION OF DAM.
THE AQUEDUCT COMMISSIONERS
NEW CROTON DAM
AT
CORNELL SITE

upon the type proposed by Delocre (Fig. 12, p. 540), but the outlines of the faces were made curvilinear in order to produce a pleasing appearance. The plan of the dam was curved to a radius of 828 feet. The wall is about 10 feet thick on top and 161 feet wide at the base. It has a length of 328 feet on the crest.

The construction of this high masonry dam proving to be successful in every respect, a number of similar works were soon built in different parts of Europe, and in Africa and Asia. A list of the most important of these works, with their principal dimensions, is given in the Table on page 559.

Prior to 1884 there was only one masonry dam in the United States that could be called a high structure, viz., the Boyd's Corners Dam, built across the West Branch of the Croton River in 1866–1873 to form a storage reservoir for the city of New York. This dam has a maximum height of 78 feet above the foundation. It is about 9 feet thick at the top, 57 feet wide at the base and has a length of 670 feet on the crest. This wall did not prove to be watertight. It leaked so badly that an earthen embankment, 20 feet wide on top and having a slope of $2\frac{1}{2}$ to 1, was placed against the upstream face of the masonry dam to stop percolation.

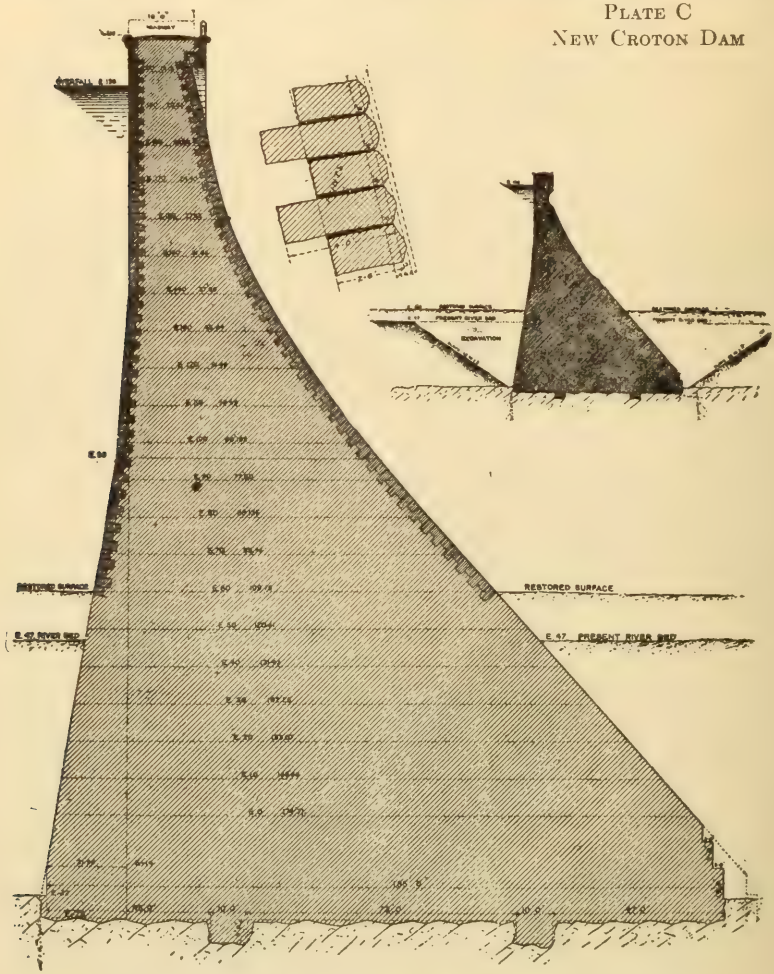
The New Croton Dam (Plates A, B, C and D). In 1884 the Department of Public Works of the city of New York proposed the construction of a high masonry dam across the Croton River, in order to form a large storage reservoir for the city. The dam was to be built near the "Old Quaker Bridge," about 6 miles above the mouth of the river. From its location the proposed reservoir wall was called the Quaker Bridge Dam. It was to have a height of about 275 feet above the foundation and a length of about 1400 feet on the crest. The construction of this structure, which was to exceed the highest existing dam by over 100 feet in height, was entrusted to the Aqueduct Commissioners, who were engaged in obtaining an additional supply of water for the city of New York. Great opposition arose to the construction of the proposed dam. After a delay of about eight years, the dam was finally built, in 1892 to 1906, about $1\frac{1}{4}$ miles upstream from the proposed site at the Quaker Bridge, and its name was changed to the New Croton Dam, to distinguish it from the Old Croton Dam, built about 3 miles farther upstream, in 1837 to 1842.

Taking the difficulty of foundation, height of structure and quantities of work involved into account, the New Croton Dam remains to the present time the greatest work of its kind. We shall give a

short description of the construction of this dam, which will serve to illustrate the manner in which such works are executed.

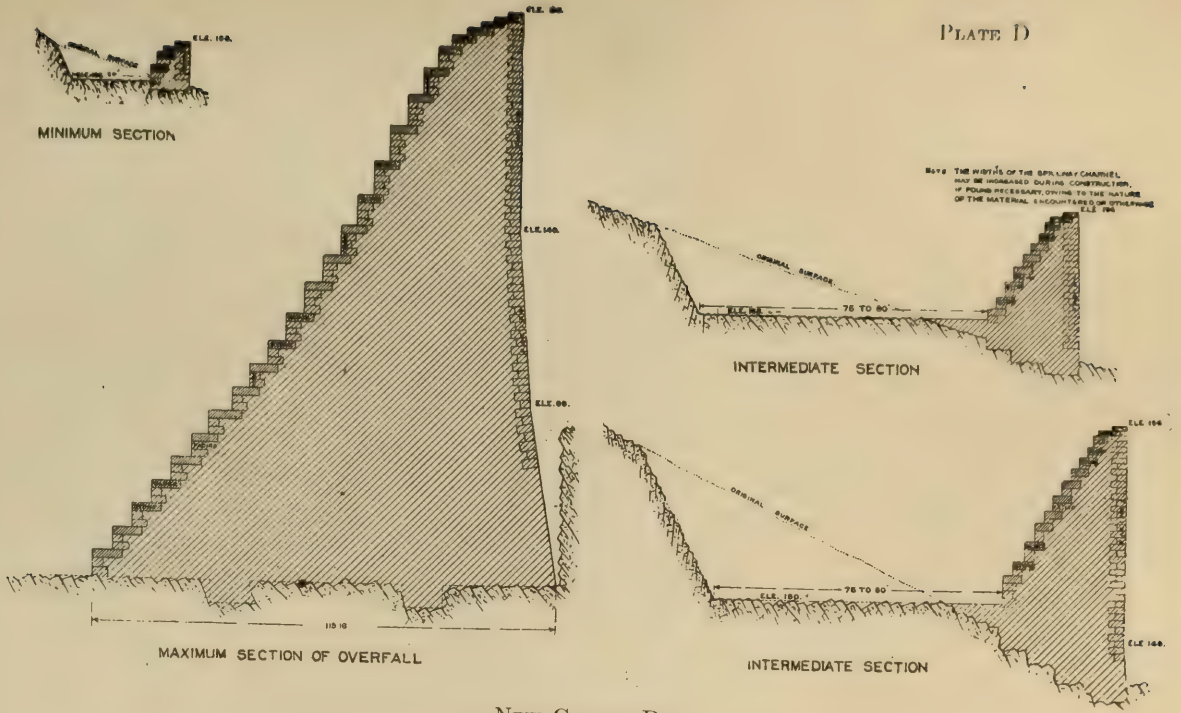
According to the original plans, the dam was to consist of a masonry wall in the center of the valley, which was to be con-

PLATE C
NEW CROTON DAM



tinued on the north by a masonry wasteweir, to be built nearly at right angles to the main dam. On the south, the masonry dam was to be extended to the hillside by an earthen dam, having a masonry corewall. The earthen dam was to have a maximum height of about 120 feet above the surface of the ground, and was

PLATE D



NEW CROTON DAM

to be separated from the main dam by a large masonry wing wall. A roadway was to be constructed on top of the dam and was to be carried across the waste channel to the north hillside by a bridge of 200 feet span. During the execution of the work, the plans described above were modified by constructing the whole dam of masonry, with the exception of an embankment, about 126 feet long, at the south end of the dam. As built, the structure consists of:

1st. A masonry dam, 1040 feet long, extending across the valley.

2d. An earthen embankment, 126 feet long, at the south end of the main dam.

3d. A masonry wasteweir, 1000 feet long, built from the north end of the main dam to the north hillside of the valley.

The maximum height of the masonry dam is 297 feet above the foundation. The earthen embankment is only about 26 feet high above the surface of the ground. It has a masonry corewall, founded on rock.

Four buttresses were built on the downstream face of the dam: two at the ends of the dam and two at intermediate points. The former project 4 feet from the face of the wall, while the latter have a projection of 15 feet. A stairway leading to the top of the dam is constructed in the northerly large buttress. On the upstream side of the dam, two pilasters, projecting $1\frac{1}{2}$ feet from the face, were built opposite to the central buttresses, by corbeling out.

The outlet from the reservoirs is controlled in two gate houses, constructed in connection with the dam and provided with suitable sluice gates. Two 48 inch scour pipes were embedded in the masonry of the dam at the former river channel. The flow through these pipes is controlled on the upstream side by means of sluice gates, and on the downstream side by means of gate valves, placed in a masonry vault.

The roadway on top of the dam, which is $19\frac{1}{2}$ feet wide, is constructed of concrete, in 6 foot sections, and is carried across the waste channel by a steel bridge, having a span of 200 feet. Iron railings are placed on both sides of the roadway, except at the buttresses and pilasters, where stone parapets are built. The drainage of the roadway is discharged by 8 inch vitrified pipes into a 4 by 4 foot sewer, constructed under the roadway.

At the site of the dam the bedrock lies at a depth of about 70 to 75 feet below the river bed. On the north side of the valley it

consists of gneiss, which rises rapidly with the hillside, but in the center and southside of the valley the rock is limestone. The great depth to which the excavation of the foundation trench had to be carried involved much expense and many risks. While this excavation was being made, the river was confined to a new channel, 125 feet wide and 1100 feet long, excavated in the rock, on the north side of the valley. The natural rock was the north side of this channel. The south side was formed by a masonry wall, about 600 feet long, which was extended at each end, by an earthen embankment (Plate B). The masonry wall was 3 feet wide on top and about 25 feet high. The embankments were 10 feet wide on top and had a height of about 30 feet. To avoid erosion the toe of the slopes of the embankments were formed, on the channel side, of heavy crib work, 10 to 12 feet high.

The water shed of the Croton River above the site of the New Croton Dam contains about 360 square miles. As part of the water coming from this drainage area was taken to the city of New York or stored in reservoirs, the depth of water in the new channel was usually only 1–3 feet. During freshets, however, it rose to a depth of 15 to 19 feet and the water poured, on two occasions, from the channel into the foundation trench. After the foundation of the dam had been laid, the construction of the masonry closed the temporary channel of the river. An outlet for the river was provided, however, by constructing through the dam at the channel an arched opening which was filled with concrete after the dam had been completed. This opening was 28 feet wide by 24 feet high at the upstream face and was reduced in area so as to be only 20 feet wide by 21 feet high at the downstream face. To afford additional relief in case of floods, and, also, to permit materials to be transported from one side to the other of the dam, a second, somewhat smaller, arched opening was constructed through the dam, south of the temporary channel.

Taking care of the Croton River during the construction of the dam, including damage due to floods, and the construction and filling of the two relief openings, cost about $422,000.

The excavation for the foundation had not only to be carried to a great depth, but had, also, to be made very wide, as the dam is 206 feet thick at its base. The material in which the trench had to be excavated consists of sand, gravel and boulders in the center of the valley and of hardpan at the south side. At first the excavation below the river bed was made with a large orange peel dredge,

having a $2\frac{1}{2}$ cubic yard dipper on an 80 foot boom. This dredge, which was kept floating in the trench, excavated about 800 cubic yards a day. After the bedrock was reached, the dredge was replaced by steam shovels, 3 being used part of the time.

Three Lidgerwood cableways, 1200 to 1600 feet long, were stretched across the foundation trench, 50 feet apart, and were used first in connection with the foundation and later in delivering the materials required for the masonry. As the trench became wider, inclined railways were built on its slopes and served for the transportation of the material excavated, which was hauled up the inclines by stationary engines and then taken to the dumping places by locomotives.

The gneiss uncovered in the foundation trench was generally much fissured. The limestone was in places sufficiently hard and watertight to form the foundation of the dam, but in other places it was so soft that it could be excavated with a pick and shovel. It had many seams, containing water under more or less pressure. In order to secure a proper foundation, the rock had to be excavated to an average depth of 20 feet. The maximum depth of the rock excavation was 54 feet and the greatest depth of the foundation trench was 123 feet below the riverbed. The total quantity of materials excavated in preparing the foundation of the dam amounted to 1,821,400 cubic yards of earth and of 400,250 cubic yards of rock.

The greater part of the dam was built of rubble faced above the surface of the ground with cut stone masonry. Large blocks, containing 1 to 3 cubic yards, were used for the rubble. They were laid so as to break joints in all directions and the spaces between the large stones were filled with mortar and spalls. All of the masonry in the foundation trench was laid in Portland cement mortar, mixed 2 to 1. Above the surface of the ground the masonry was laid in American cement mortar, mixed 2 to 1, except in winter, when Portland cement mortar, mixed 3 to 1, was used. In extending the dam to the south side of the valley, where the original plans contemplated the construction of an earthen embankment, the wall was built of Cyclopean masonry, consisting of large blocks of stone, bedded in and surrounded by concrete, mixed quite wet.

The plant required for the construction of the dam, cost about $750,000 and the salvage value was only about $150,000. Large pumps were needed to keep the foundation trench dry. The contractors used for this purpose three large Worthington duplex,

compound pumps, each having a capacity of 4,000,000 gallons per 24 hours, and two duplex Worthington pumps, having each a capacity of 2,000,000 gallons per 24 hours. Two of these pumps were usually held in reserve. In dry weather about 5,000,000 gallons per day had to be pumped from the foundation trench, but in wet weather about twice this quantity had to be pumped.

The construction of the New Croton Dam was begun in the Fall of 1892 and was practically completed by January 1, 1906. The cost of the dam, not including engineering, land and legal expenses, was about $6,900,000.

The Aqueduct Commissioners built, besides the New Croton Dam, five other masonry dams, 70 to 170 feet high, to form additional storage reservoirs for the city of New York. In connection with the Catskill Aqueduct, which is now being constructed to secure an additional supply of water for the city of New York, an important masonry dam has just been completed across Esopus Creek, at Olive Bridge, in Ulster County, N. Y. This wall is 252 feet high and 1000 feet long on top. It is extended on each flank by an earthen dam, having a masonry corewall.

In 1900–1905 a masonry dam was built across an affluent to the Passaic River, to form a storage reservoir for Jersey City, N. J. This wall, known as the Boonton Dam, is 114 feet high and 2150 feet long at the crest.

In 1900–1906 the Wachusett Dam, 228 feet high and 850 feet long at the crest, was constructed across the south branch of the Nashua River. It forms a reservoir of about 63,000,000,000 gallons capacity for the Metropolitan District of Boston, Mass.

The masonry dams, described above, are the principle high reservoir walls in the eastern part of the United States. As they are all constructed across wide valleys, they were built straight in plan.

Curved Dams. Since 1884 quite a number of masonry dams have been built west of the Mississippi to store water for irrigation. Most of these structures are built across narrow canyons, and their plans are, in all cases, curved upstream to secure additional strength.

The Bear Valley Dam (Fig. 7) was one of the most remarkable of these structures. It was constructed in 1884 in the Bernardino Mountains in California to form a large reservoir for irrigation. As all the cement, tools, and supplies had to be hauled for about 70 miles over rough roads to the site of the dam, and as the available financial means were very limited, the engineer in charge of

the work, Mr. F. E. Brown, decided to curve the plan of the dam and to depend solely upon the dam's acting as a horizontal arch in resisting the thrust of the water. The profile adopted for this structure is only 20 feet wide at the base for a height of 64 feet. With the reservoir full the line of pressure fell 14.9 feet outside of the base. For many years this bold structure stood, a worthy rival of the famous Zola Dam described on page 520. This dam

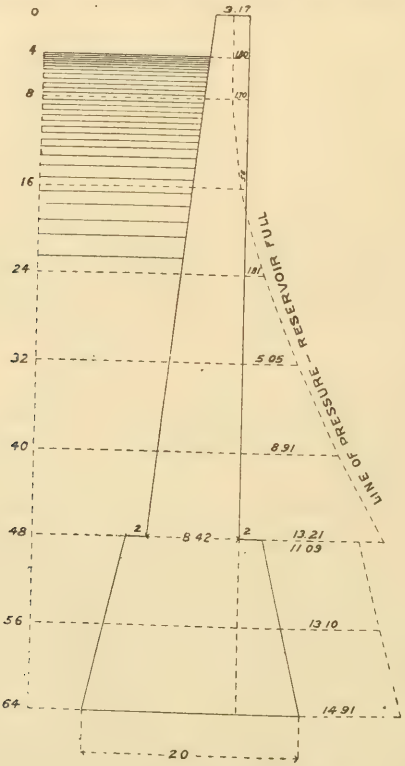
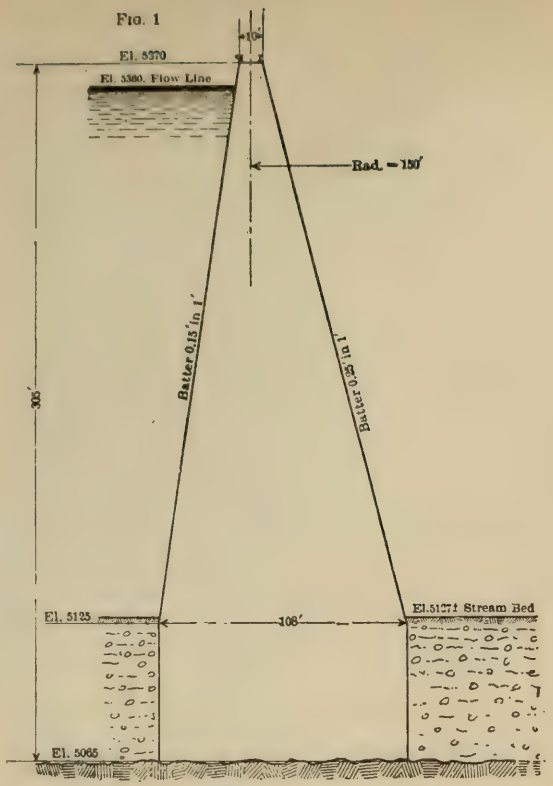


Fig. 7. Bear Valley Dam

was replaced by a substantial reservoir wall, built about 200 feet further downstream in 1910.

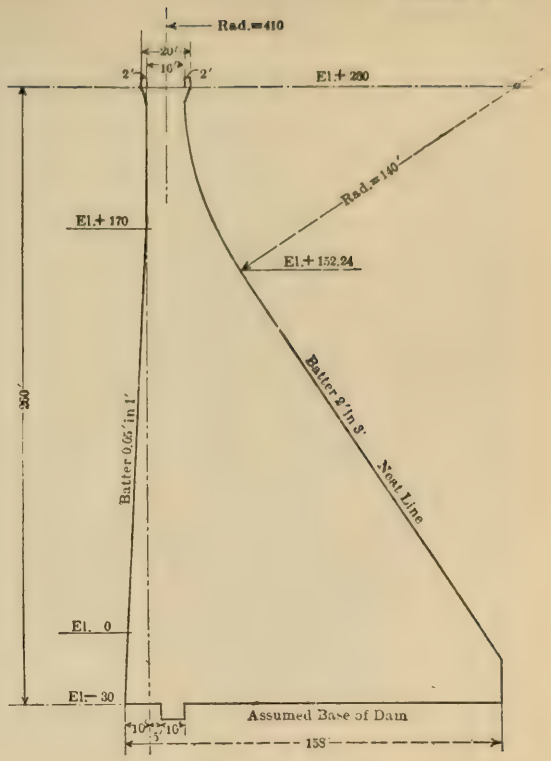
Under the direction of the United States Reclamation Service, three high masonry dams have been recently constructed, viz., the Roosevelt Dam, 280 feet high, built 1905–1911; the Pathfinder Dam, 207 feet high, built 1905–1910; and the Shoshone Dam, 325 feet high, built in 1905–1910 (Plate E). All of these dams are curved upstream in plan and their stability is made to depend

FIG. 1



SHOSHONE DAM

PLATE E



PATHFINDER DAM

upon their acting as horizontal arches, as their profiles are much reduced from what is known as a "gravity section" viz.: a section which enables a dam to resist the water pressure by its weight alone. In determining the profiles of these dams the stresses produced in the masonry by changes of temperature were taken into account.

A number of curved dams were built of concrete in New South Wales, Australia, in 1896 to 1906.[1] All of these structures depend for their stability, when the reservoirs are full, upon their acting as horizontal arches. The maximum pressures in the masonry of some of these dams amount to 15 to 24 tons per square foot.

The early French writers recommended that the maximum pressures in the masonry or on the foundation of a dam be limited to 6 tons per square foot. Their successors gradually raised this limit to 8 to 10 tons per square foot. The great height of the New Croton Dam made it necessary to increase the limit of pressure to 16 tons per square foot to keep the bottom width of the dam within reasonable dimensions. The experience with the Australian Dams, mentioned above, shows that good Portland Cement mortar can sustain safely pressures up to 25 tons per square foot.

Failures of Dams. Very few high masonry dams have failed. The only cases known to the writer are given in the following table:

Failures of High Masonry Dams

YEAR	NAME	LOCATION	HEIGHT	CAUSE OF FAILURE
1802	Puentes	Spain	164 ft.	Pile foundation.
1881	Habra	Algiers	110 "	High flood; poor masonry.
1895	Bouzey	France	72 "	Pervious sandstone foundation.
1900	Austin	Texas	68 "	High flood; poor foundation.
1911	Austin	Pennsylvania	50 "	Pervious foundation.

The failure of the Puentes Dam has been described on page 518.

The Habra Dam (Fig. 8), in Algiers, was built in 1865–1871. The profile of the dam was calculated by Delocres method. The dam was built straight in plan. It had a length of 1066 feet and was flanked by a wasteweir 410 feet long, which made an angle of 35 degrees with the main dam. The maximum height of the wall was 110 feet. The dam was ruptured in December, 1881, during a severe freshet, which caused the water to rise to height

[1]Concrete and Masonry Dam Construction in New South Wales by Leslie Augustus Burton Wade, M. Inst. C. E. See Proc. Inst. C. E., Vol. 178, p. 1)

of 11.5 feet above the top of the dam. This failure was attributed to bad foundation and poor masonry, especially, as regards the quality of the hydraulic lime that was used for mortar.

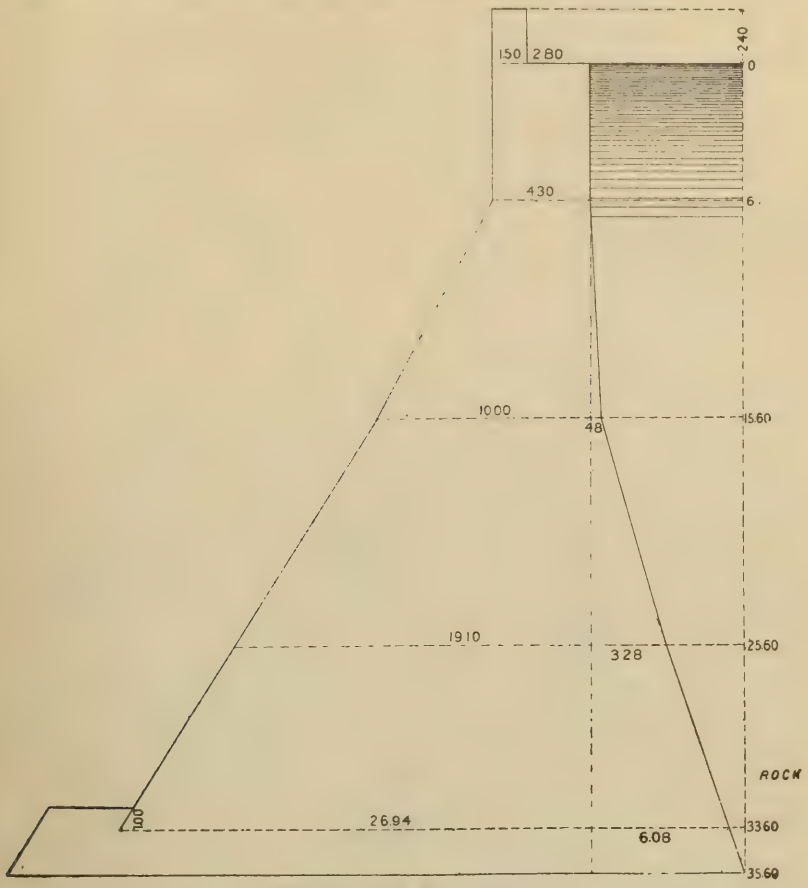


FIG. 8. THE HABRA DAM

The Bouzey Dam was built in 1878–1881, near Epinal, France. It was 1700 feet long on top and had a maximum height of 72 feet above the foundation. The foundation of this dam consists of red sandstone, that is badly fissured and quite permeable. To prevent percolation under the dam, a cutoff wall, 2 metres thick and about 3 metres deep, was built, on the upstream face the of dam, but it was not carried down to sufficient depth to be effective. The dam was completed in 1880 but the reservoir was not filled

until 1884. When the water reached a level of 10.5 feet below the top of the dam, a portion of the wall, about 440 feet long, was shoved downstream, so as to form a curve, having a versed sine of 1.1 feet. Considerable leakage under the dam occurred at this time. The reservoir was emptied and all seams in the rock, that were discovered, were closed with masonry or grout. To prevent the dam from sliding, an abutment was built on the downstream side of the dam, with which it was connected by an inclined wall, toothed into the

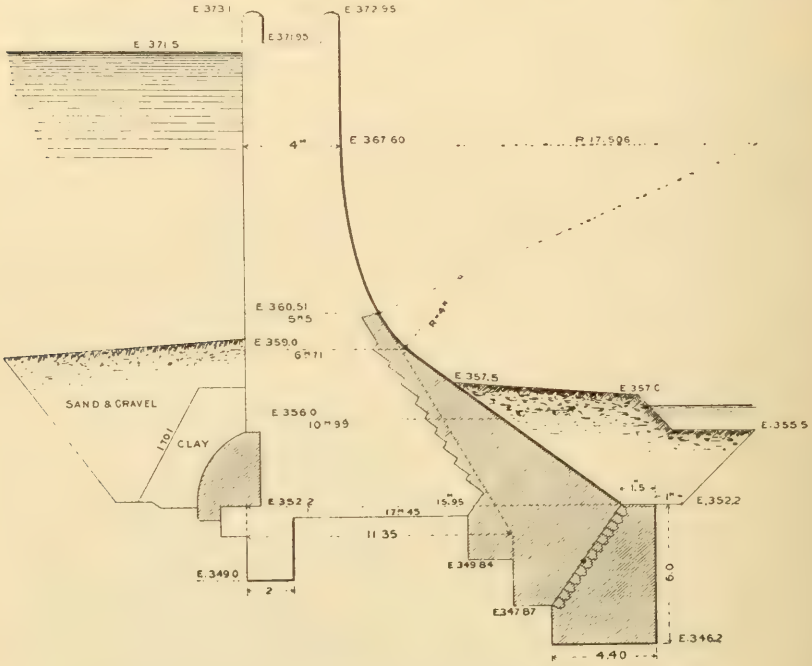


Fig. 9. The Bouzey Dam

masonry of the dam (Fig. 9). A block of masonry was also built on the upstream face to close a joint, which had opened between the main dam and the cutoff wall, and was surrounded by a bank of puddle, about 10 feet thick. The masonry added to the dam is shown by the shaded portions of Figure 9. Drains were put in the masonry to carry off any water that might leak under the dam. With these reinforcements the dam stood for a few years, but on April 27, 1895, the water being at its highest level in the reservoir, about 594 feet of the central part of the dam was suddenly overturned at a plane about 33 feet below the top of the wall. The

fracture was almost horizontal longitudinally. It was level transversely for about 12 feet, and then dipped toward the downstream face. The failure of this dam caused a great loss of life and of property. It is supposed to have been caused by an upward pressure under the base of the dam, which, combined with the horizontal thrust of the water, caused a greater tension at the upstream face than the masonry of the dam could resist.

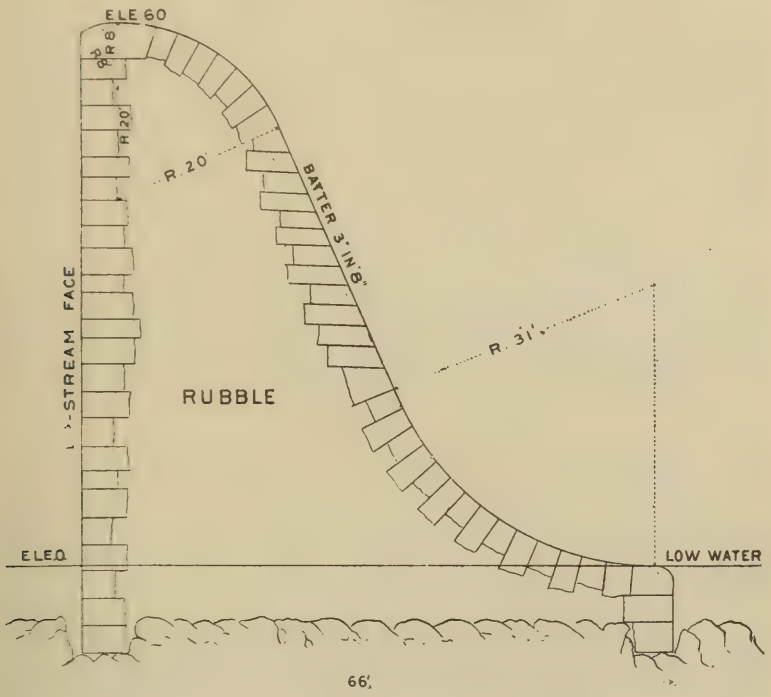


FIG. 10. THE COLORADO DAM

The Colorado Dam (Fig. 10) was built in 1891–1892 across the Colorado River, about two miles above Austin, Texas, to supply this city with water and power. At the site selected for the dam, the river flows in a deep gorge in limestone. The dam was founded on the rock forming the river bed, which was only excavated to a depth of about 4 feet, at the face of the dam. The foundation was very bad at certain places. About 150 feet from the eastern bluff a fault, 75 feet wide and extending to an undetermined depth, was found. It was full of adobe, or pulverized rock, with an occa-

sional streak of red clay. At this point the excavation was carried down the depth of 8 to 10 feet at the upstream side of the dam, and the base of the dam increased from 4 to 15 feet in width. Opposite the fault, clay was dumped against the upstream face of the dam, as an additional protection. For about 350 feet east of the fault the rock remained of poor quality, but for the remaining distance it was hard.

After a heavy rain fall on April 6 and 7, 1900, the river rose to a level of 11.07 feet above the crest of the dam. This caused the dam to give way, about 300 feet from the east end. The current pushed its way through the gap that was made and shoved two sections of the dam, one on each side of the gap, and each about 250 feet long, bodily, 50 to 60 feet downstream. These sections were not turned over in the least and remained standing almost parallel with their original position. Forty minutes after the break, the western section and part of the easterly one turned over towards the dam and disappeared in the torrent.

The failure of this dam has been attributed to poor foundation and the unexpectedly high rise of the river. What may have been contributed to this disaster is the fact that the downstream toe of the dam had been undermined by the water flowing over the dam and by a steady stream from the powerhouse which flowed in a tailrace along the toe of the dam to the channel of the river.

The Dam at Austin, Pennsylvania (Plate F) was built in 1909 on a sandstone foundation. It was about 50 feet high and had a length of about 550 feet at the crest.[1] This structure was ruptured on September 30, 1911. As some important lititagion resulting from the failure is still pending, the writer will not discuss the causes of this disaster.

Theory of Masonry Dams. The first rational theory of the proper design for the profile of a masonry dam was advanced by the French engineer de Sazilly in a memoir published in the "Annales des Ponts et Chaussées" for 1853. Assuming the dam to be built on an unyielding foundation, de Sazilly pointed out that the safety of the structure depended upon the compliance with the following two conditions:

1st. The pressures sustained by the masonry or by the foundations must never exceed certain safe limits.

2d. There must be no possibility of any portion of the masonry sliding on that below or of the whole wall's sliding on the foundation.

[1] See *Engineering News* for March 17, 1910.

PLATE F

DAM AT AUSTIN, PENN.

DAM AT AUSTIN, PENN.

It would be very difficult, if not, indeed, impossible, to devise a formula containing both of the above conditions. De Sazilly states, however, that no masonry dam had been known to fail by sliding, and he recommended, therefore, that the profile of a dam be designed solely with reference to the first of the conditions, leaving it to a subsequent trial to determine whether the second has been fulfilled. This will generally be found to be the case, especially if the assumed limit of pressure is not very high and the dam has considerable topwidth. Should it be found that the wall or part of it might slide, then de Sazilly's method would be to increase the thickness of the profile by recalculating it for a lower limit of pressure. This writer pointed out that two extreme cases must be considered, in determining the maximum pressures in the masonry or on its foundations, viz.:

1st. Reservoir full.

2d. Reservoir empty.

These two cases give the extreme positions of the lines of pressure in a dam, the first causing the maximum pressure in any horizontal plane to be at the front (downstream) face of the wall, and the second producing it at the back (upstream) face. The practical considerations of economy require that a dam should contain the minimum amount of material consistent with safety. Having established a fixed limit of pressure, de Sazilly's ideal profile is that in which the maximum pressures in both faces just reach the limit. He called this "the profile of equal resistance." In calculating the pressures in the masonry de Sazilly assumed the wall to be divided by horizontal planes into imaginary courses and considered the pressures in the masonry to be distributed according to the laws of a "uniformly varying stress," as explained hereafter.

In seeking to find formulae for determining a "profile of equal resistance," de Sazilly experienced no difficulty in obtaining the correct differential equations, but found it impossible to integrate them, and had, therefore, to abandon the idea of finding the proper curves for the faces of the "profile of equal resistance." The difficulties of the integration may, however, be avoided by substituting for curved outlines polygonal or stepped faces. De Sazilly adopted the latter plan, for which he devised formulae. The profile type which he recommended, calculated for a depth of 50 metres (164 feet) is shown in Figure 10.

M. Delocre was the next engineer who advanced a method for determining a correct profile for a masonry dam. He assumed

the same conditions and distribution of pressures as de Sazilly, but differed from this writer in advocating a polygonal instead of a stepped profile. Delocre demonstrated that the latter type involved in the steps a waste of masonry and an expensive class of work. He devised lengthy equations, some of them of the sixth degree, for calculating profiles according to his method, and also investigated the additional strength which might be obtained by

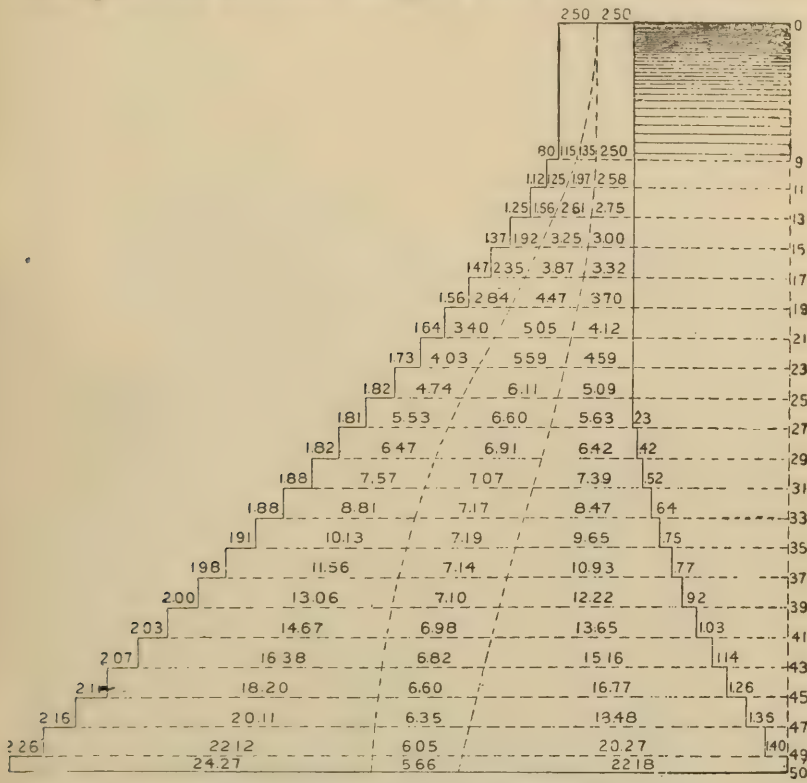


Fig. 11. De Sazilly's Profile-Type

building a dam on a horizontal curve in plan. The profile formed by Delocre's method is shown in Figure 12. The results of Delocre's studies were known in 1858, and formed the basis of the design for the celebrated Furens Dam, described on page 522. It was not, however, until after the completion of this work that M. Delocre published in the "Annales des Ponts et Chaussées " for 1866 a memoir giving the details of his researches.

An important consideration in determining the profile of a masonry

dam is the maximum pressure to which the masonry or the foundation may be subjected. How do the stresses resulting from the weight of the masonry, and the thrust of the water distribute themselves in a dam? Thus far no satisfactory answer has been given to this question, and we are, therefore, obliged as in many other engineering problems, to make certain assumptions for lack of

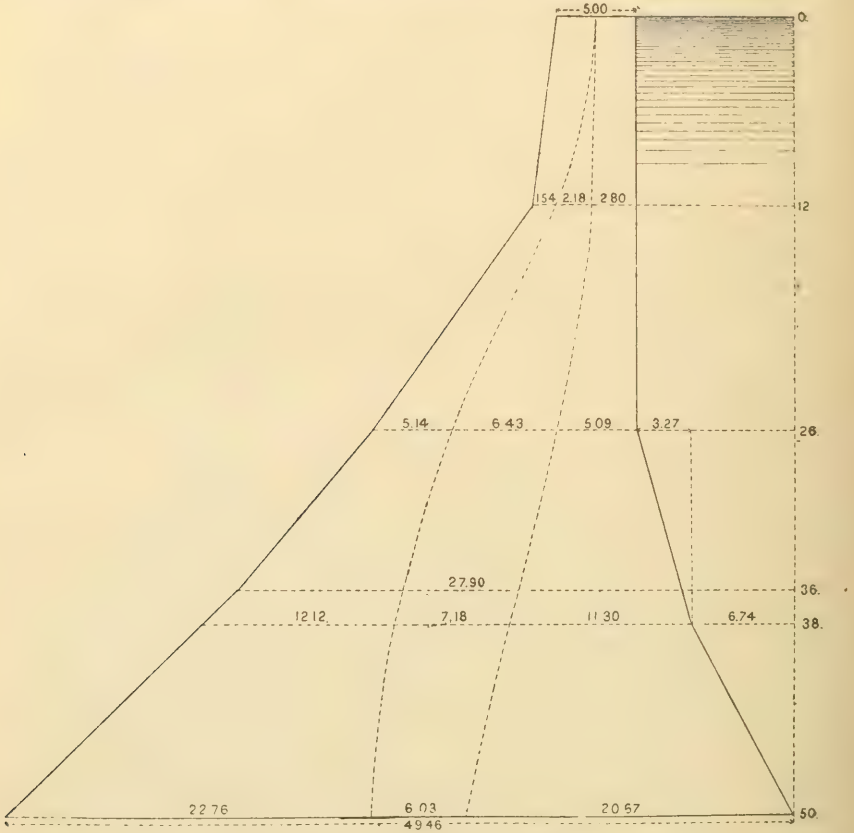


Fig. 12. Delocre's Profile-Type

exact knowledge. De Sazilly, and practically all writers who followed him in investigating the subject of masonry dams, assumed that the pressures in a masonry dam distribute themselves as a uniformly varying stress. When the reservoir is empty, the only force acting is the weight of the masonry. When the reservoir is full the weight of the masonry and the horizontal thrust of the water combine to form an inclined resultant. In determining the

PLATE G

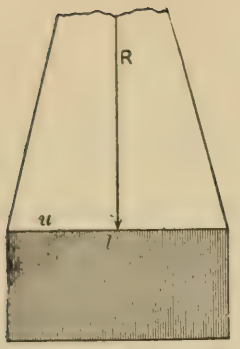


FIG. 1

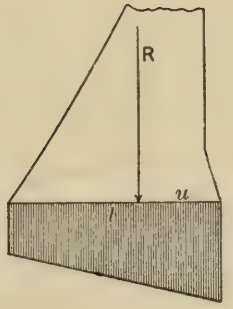


FIG. 2

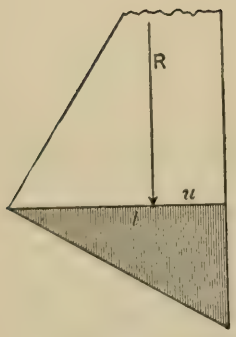


FIG. 3

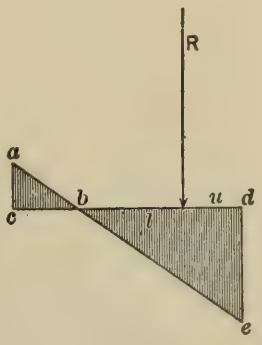


FIG. 4

pressures in the masonry for each one of the horizontal courses, into which a dam is supposed to be divided, to facilitate calculation, de Sazilly and Delocre considered only the vertical component of the inclined resultant, for the case of reservoir full.

The manner in which a vertical force is assumed to distribute itself in the masonry at the foundation or at any assumed horizontal joint is shown in Plate G. In Figure 1 of this plate (R) represents the resultant of the vertical forces acting on the dam, or the vertical component of an inclined force, as the case may be. The shaded portions of the figures show how (R) is distributed and give, also, the reactions of the foundation, as action and reaction must be equal and in opposite directions. Where (R) intersects (L), which may be the base or any other assumed horizontal point, at the center, (R) is distributed uniformly over (L) and this is shown graphically by a rectangle. If (R) intersects (L) to one side of the center, the diagram of distribution of pressure is represented by a trapezoid, which becomes a triangle, where (R) intersects (L) just at the limit of its center-third. Should (R) fall outside of this center-third, the distribution of pressures will be given by two triangles (Plate G, Fig. 4), one of them representing a negative stress viz., tension.

It is somewhat difficult to understand how tension can occur in a masonry dam. With eccentric loading, such as is shown in Figure 4, (R) is supported on only part of (L), and the tendency of the dam to rotate about the edge (d), or a point near it, is partly resisted by tension in the masonry. As dams are actually built, the resultant pressure for reservoir empty is always nearer the upstream than the downstream face of the wall and consequently the greatest pressures in the masonry occur at the upstream face. For the case of reservoir full the opposite occurs, the greatest pressures being at the downstream face.

About 1871 Professor W. J. M. Rankine was consulted about a masonry dam that was to be built at Bombay, India. Rankine made a very thorough study of the proper design of masonry dams and gave the conclusions at which he arrived in a report on "The Design and Construction of Masonry Dams" which was published in "The Engineer, London" for January 5, 1872. While accepting generally the principles laid down by de Sazilly and Delocre, he improved their theories in some respects. These engineers, as stated above, had only considered, for the case of reservoir full, the pressures produced by the vertical component of the inclined resultant

pressure, and they had taken the same limits of pressure for the masonry at both faces of the dam. Professor Rankine states, however, in this connection: "It appears to me that there are the following reasons for adopting a lower limit at the outer than at the inner face. The direction in which the pressure is exerted amongst the particles close to either face of the masonry is neces-

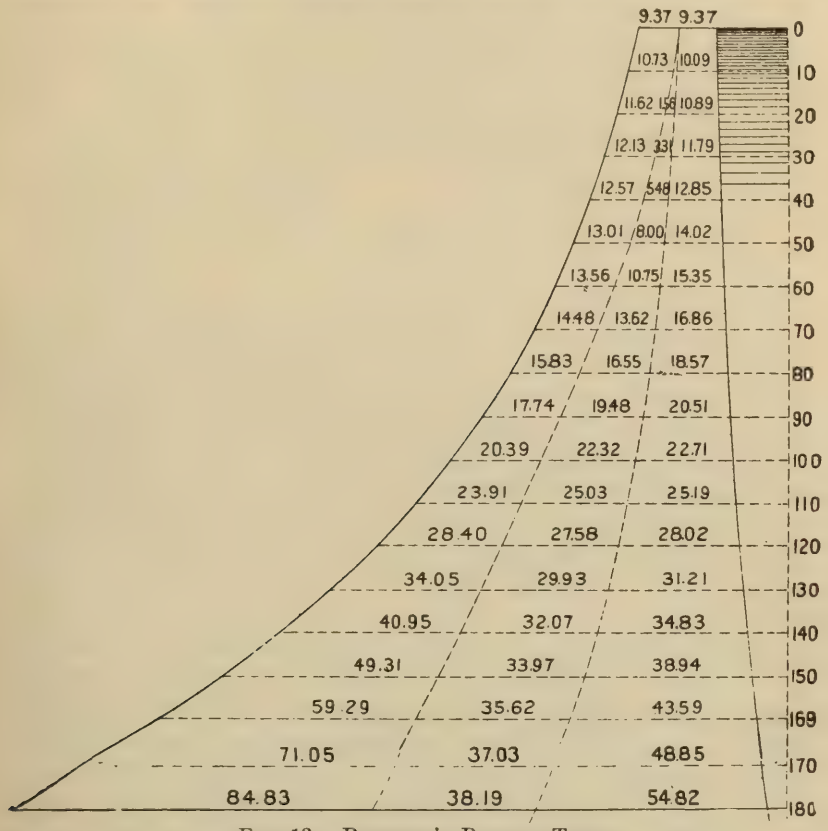


FIG. 13. RANKINE'S PROFILE-TYPE

sarily that of a tangent to that face; and, unless the face is vertical, the pressure found by means of the ordinary formulae is not the whole pressure, but only its vertical component; and the whole pressure exceeds the vertical pressure in a ratio which becomes the greater, the greater the 'batter,' or deviation of the face from the vertical. The outer face of the wall has much greater batter than the inner face; therefore, in order that the masonry of the

outer face may not be more severely strained when the reservoir is full than that of the inner face when the reservoir is empty, a lower limit must be taken for the intensity of the vertical pressure at the outer face than at the inner face."

Professor Rankine did not attempt to determine the ratio which the limits of the vertical pressure at the front and back face ought to bear to each other by any mathematical deduction, as he deemed the data upon which it would have to be based too uncertain. In choosing the limits of pressure for the profile accompanying his report (Fig. 13), he was guided entirely by what experience had proved to be safe and adopted:

	Limit of vertical pressure, in pounds per square foot
For front (downstream) face	15,625
For back (upstream) face	20,000

The same reasoning which lead Rankine to recommend a lower limit of vertical pressure at the front face than for the back face induced him to make the pressures at the front face diminish as the batter increases. Here, too, he followed practical examples, as he thought it impossible in our present state of knowledge to deduce a law for this diminution. He designed his profile, therefore, in such manner that the maximum pressure at a depth of 150 feet would equal the pressure at the same depth in the Furens Dam; viz., $6\frac{1}{2}$ kilos per square centimetre, or about 6.65 tons of 2,000 pounds per square foot. Below this depth the maximum pressures diminish gradually.

Another principle pointed out by Professor Rankine is that no tension must be allowed in the masonry. Theoretically this would occur (Plate G, Fig. 4), whenever the line of pressure lies at any point outside of the center third of the profile. The stability of the dam against overturning depends upon the position of the line of pressure. For the above reasons Rankine limits these lines (reservoir full or empty) to the center third of the profile.

The conditions given by Rankine do not prescribe any definite form of profile, but when we add the consideration of economy, requiring the minimum amount of material consistent with safety, the choice of form becomes very limited. The types of de Sazilly and Delocre involve very lengthy calculations. Professor Rankine endeavored to find simpler formulae. One of the effects of his using a higher limit of pressure for the back face than for the front is to reduce the batter of the former considerably from that of the

French types. The vertical component of the water-pressure on the back of a dam can, therefore, add but little to the stability of the wall. Rankine neglected this component in his formulae, as the slight error thus introduced is in the direction of safety, and also simplifies largely the mathematical investigations.

As regards the profile accompanying his report, he says, "In choosing a form in order to fulfil the conditions without any practical important excess in the expenditure of material beyond what is necessary, I have been guided by the consideration that a form whose dimensions, sectional area, and centre of gravity under different circumstances are found by short and simple calculations, is to be preferred to one of a more complex kind when their merits in other respects are equal, and I have chosen logarithmic curves for both the inner and outer face, and the common subtangent being 80 feet for both."

The formulae given by Professor Rankine for determining the thickness, area, etc., of this profile are extremely simple; but they produce only this one profile, whose dimensions might as well be calculated once for all. Change the data upon which it is based, such as the weight of masonry, limiting pressures, etc., and the simplicity of this method disappears. Rankine states that his general formulae which we would have to employ in such case are "incapable of solution by any direct process." They can, however, be solved approximately by a process of trial and error, involving the higher mathematics.

The Toolsee Dam, 79 feet high, built at Bombay, India, is, as far as the writer knows, the only dam built according to Rankine's logarithmic profile.

Since Rankine's time a number of engineers have proposed formulae for determining the proper profile of a masonry dam and others (Krantz, Crugnola, Harlacher, etc.) have proposed profile types without giving formulae for determining their dimensions. How much these different authorities differ from each other is shown in Figure 14.

In calculating the maximum pressures in the masonry the method usually employed has been to divide the dam by horizontal planes into courses and to figure the pressures at both faces of each course for reservoir full and reservoir empty. Professors Alcherly and Pearson startled the profession in 1904 by demonstrating, in a paper on "Some disregarded points in the stability of masonry dams," [1] that greater strains might be found by assuming a dam to

[1] Published in "Draper's Company Research Memoirs," Technical Series II, London, 1904.

be divided into vertical courses instead of into horizontal ones. These investigators, and some who followed them, made experiments with models of dams, made of uniformly elastic substances, with a view to finding the actual distribution of pressures in a masonry dam. While such researches are very interesting and may add to our scientific knowledge, it is very doubtful to what extent results obtained with such models could be safely applied to the design of actual dams. The masonry in such structures forms by

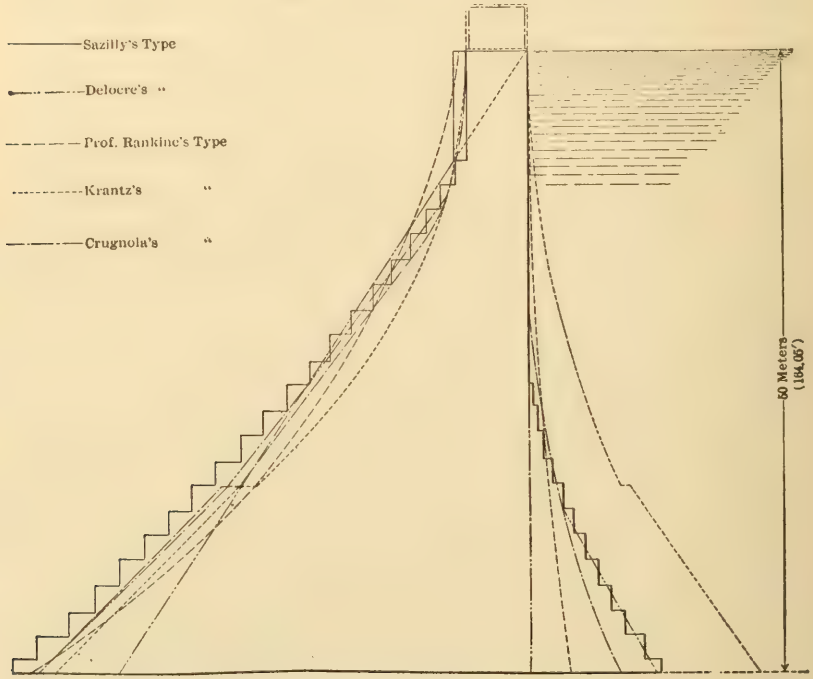


FIG. 14. COMPARISON OF PROFILE-TYPES

no means a uniformly elastic mass, such as exists in the models referred to above. Experience has proved that dams designed on the assumption that the pressures in the masonry are distributed as uniformly varying stresses are safe. There is no need of making them any thicker. On the other hand, if we should reduce the thickness to correspond to new theories, the dams would not have sufficient strength to resist sliding or shearing.

The early writers on the subject of masonry dams assumed the wall to be built of impervious masonry and founded on rigid,

impervious rock. Such ideal conditions rarely exist in actual practice. The failures of the Bouzey Dam in France and of the two Austin Dams in America were undoubtedly largely due to the fact that water percolated through fissures in the rock under the dams and exerted considerable upward pressure on the bases of these dams. Alarmed by these failures some engineers have recommended that in designing the profiles of a masonry dam, the full pressure of the water in the reservoir should be assumed to act upwards under the whole base of the dam, but such an extreme view need rarely be considered. When dams are founded on good rock, the area of fissures, where an upward pressure could be exerted on a dam, forms a very small percentage of the total area of the base of the dam. The rock would have to be badly fissured to permit an upward pressure on half the area of the base.

A great many masonry dams have been built in this country and abroad without any attention having been paid in designing their profiles to the possibilities of an upward pressure under the base. The list of such works includes the New Croton, Titicus, Boonton, Sodom Dams in the United States, and practically all of the reservoir walls built by French engineers in their own country and in Algiers. Some of these structures have been standing successfully for nearly half a century. If a large upward pressure were exerted under these dams, the lines of pressure for reservoir full, would become quite eccentric, causing considerable tension at the upward stream faces and leading in some cases to failure. There is not the slightest indication that such a condition exists in these reservoir walls, and experience warrants, therefore, to neglect the consideration of an upward pressure in designing dams that are to be founded in good rock. When, however, the wall is to be built on a very pervious foundation, such as sandstone, or on rock that is very badly fissured, prudence dictates that an upward pressure be considered in designing the profile. For lack of any definite knowledge as regards the possible magnitude of this force, some assumption, or rather guess, must be made. The extreme view of taking the upward pressure to be equal to the full hydrostatic head of the reservoir, acting on the whole base of the dam, which is equivalent to supposing the dam to float in water, leads to a profile whose dimensions are excessive. If safety were the only consideration we might adopt the simple rule of making the width of the dam, at any level, twice the height, and there would be no danger of failure. We have, however, to consider

the cost of the work. Safety and economy tend in opposite directions and the skill of the engineer consists in obtaining the required security, at a minimum of expense.

As far as the writer knows, the Wachusett Dam in Massachusetts is the first reservoir wall whose profile was designed by con-

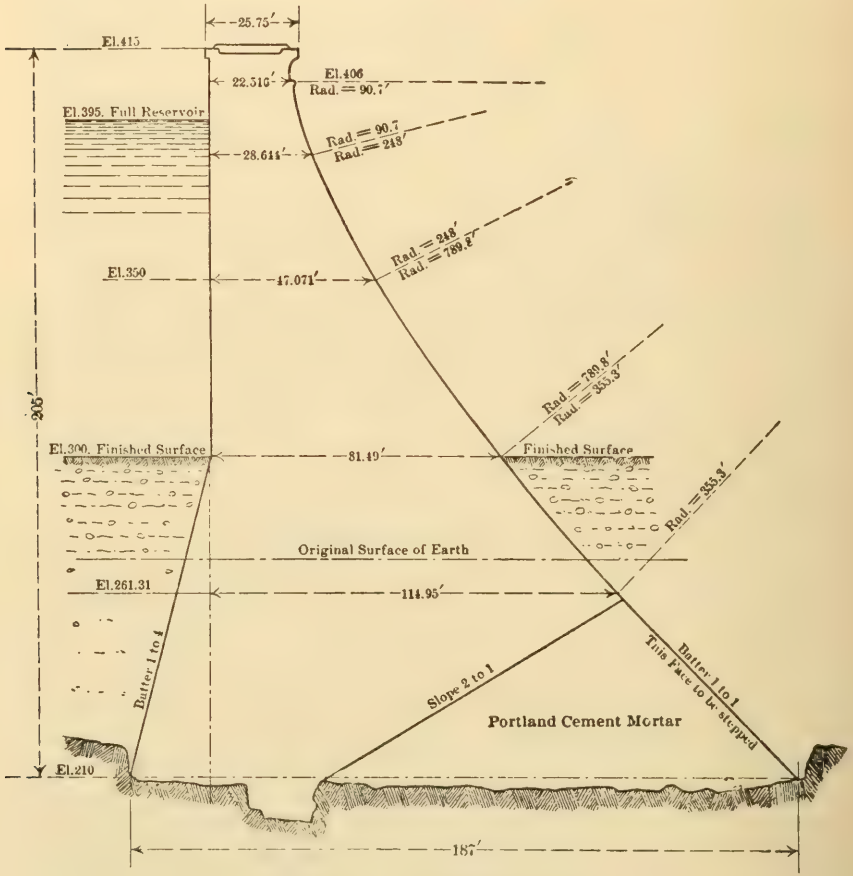


Fig. 15. Wachusett Dam

sidering upward pressure. This dam was to be built across the South Branch of the Nashua River, only a half mile above the town of Clinton, whose population amounted to above 13,000 at the time. Great apprehensions were felt in Clinton as regards the possibility of the dam's failure, and there would have been a strong opposition to the construction of the dam, if it had not been designed

to have a very large margin of safety. This was accomplished by assuming a large upward pressure under the base of the dam and also, an ice pressure of 47,000 pounds per lineal foot at the flowline of the reservoir. The upward pressure was taken to be two thirds of the full hydrostatic pressure of the reservoir at the upstream face of the dam and assumed to diminish regularly so as to be zero at the downstream face. The effect of these two forces increasing the profiles is shown in Figure 15.

The masonry dams built in the Croton Watershed from 1888 to 1905 were all designed by the late Alphonse Fteley, past president American Society of Civil Engineers, without any regard to upward water pressure or to ice pressure. The designs of two later reservoir walls in the Croton Watershed: the Cross River Dam, 170 feet high, built in 1905 to 1909; and the Croton Falls Dam, 173 feet high, built in 1906 to 1911, were based upon the conditions assumed in determining the profile of the Wachusett Dam, viz.: upward pressure under the base and ice pressure at the flowline. The latter force was taken as 16,000 pounds per lineal foot for the Cross River Dam and as 24,000 pounds per lineal foot for the Croton Falls Dam.

Both of these dams are built on affluents of the Croton River, only a trifling distance from the New Croton Reservoir, which has a capacity of 34,000,000,000 gallons. A failure of either of these dams could not lead to a frightful disaster. Under these circumstances it may be questioned whether the large profiles adopted for these two dams are justifiable.

Reference has been made above to ice pressure against a dam. The first suggestion that such a force be considered was made in a report on the proposed Quaker Bridge Dam by a board of experts, consisting of Joseph P. Davis, James J. R. Croes and Wm. F. Shunk, in which the following statement occurs:

"In our search for information upon the expansive force of ice in place, caused by increase of temperature, we found little of value recorded; but we obtained valuable, though somewhat conflicting information by correspondence and personal interviews which information, supplemented by experimental data, concerning its strength, elasticity and rate of expansion under rising thermometer, has lead us to the opinion that the dam should be proportioned to resist a thrust at the highest ice line of about 43,000 pounds per lineal foot." Ice confined, as between two bridge piers, exerts a great pressure in expanding, but the writer thinks it very doubtful

whether such pressure is exerted against a masonry dam, forming a large reservoir with sloping banks. In such cases the ice is shoved up on the banks and breaks, following the line of least resistance. A great many weak mill dams exist, which would be ruptured each year, if ice exerted much pressure against them.

There is only one case on record, so far as the writer knows, in which ice pressure is supposed to have been the primary cause of the failure of a dam, viz.; that of the dam of the Minneapolis Mill Company, at Minneapolis, Minn. This dam is 535 feet long and about 18 feet high. A retaining wall, 350 feet from the dam and parallel thereto, forms the opposite side of the pond (Fig. 16). In winter ice, 4 feet thick, forms in the pond and ice, 10 to 12 inches thick, freezes against the upstream face of the dam to a depth of 10 to 12 feet.

During the week the pond, with its ice cover, is drawn down two

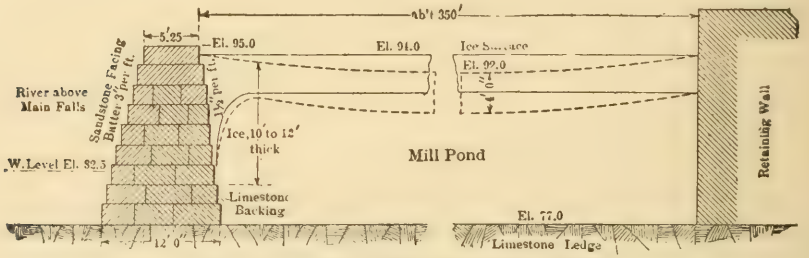


FIG. 16. DAM AT MINNEAPOLIS, MINN.

or more feet to meet the demands for power, but on Sunday the water and ice rises to the normal level of the pond. The ice frozen to the faces of the dam and of the retaining wall remains, however, adhering to the masonry. This unequal motion causes cracks in the sheet of ice covering the pond, which are soon closed by expansion or by freezing. Under these circumstances it is evident that the ice exerts against the dam, in addition to the pressure caused by expansion, a force somewhere like that made by means of a toggle joint.

The dam was built in 1893 and stood successfully for several years, bearing the great pressures to which it was exposed. In the spring of 1899, however, a section of the waste weir, 170 feet long, failed by sliding. It had been noticed in the preceding winter that the ice pressure had caused the dam to revolve slightly about an axis near its downstream toe. The top of the dam was moved in this manner about a foot downstream, without the wall's sliding.

This motion was stopped by cutting the ice along the dam, which returned slowly about half way to its original position. To prevent a repetition of this motion, 4 inch holes were drilled, 25 feet apart, through the dam and 4 feet deep into the bedrock. Three inch anchor rods were put in these holes and were surrounded with grout. These rods snapped like pipestems when the failure occurred the following spring.

In 1895 Mr. John D. Van Buren, M. Am. Soc. C. E., advocated in a paper on "High Masonry Dams," [1] that the profile of a masonry dam should be designed by taking into consideration the full upward pressure, due to the head or the reservoir under the base of the dam, and also, in northern latitudes, an ice pressure of about

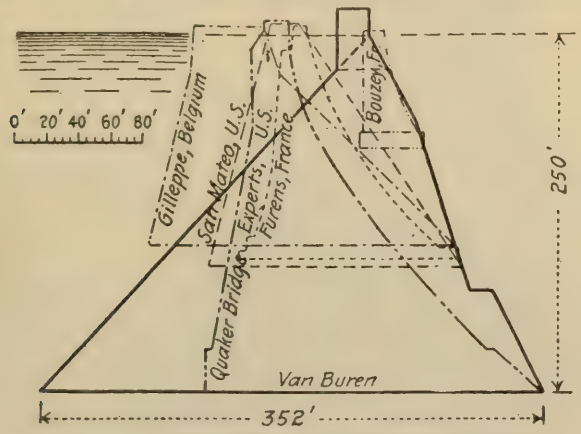


FIG. 17. COMPARISON OF PROFILES OF DAMS

40,000 pounds per linear foot of dam. Based upon these conditions Mr. Van Buren arrived at the profile which has a base of 352 feet for a depth of water of 250 feet. How much this profile differs from those of some existing high dams is seen on Figure 17. Had the New Croton Dam been designed according to Mr. Van Buren's recommendation, its base would have been about 400 feet wide, instead of 206 feet, as actually constructed, and the cost of construction would have been nearly doubled.

Mr. John R. Freeman, M. Am. Soc. C. E., advocated in a letter to the *Engineering News* [2] written soon after the failure of the dam at Austin, Pennsylvania, practically the same conditions as regards upward pressure and ice pressure proposed by Mr. Van Buren.

[1] Trans. Am. Soc. C. E., Vol. XXXIV, p. 493.
[2] Engineering News, October 19, 1911.

It is not likely that these extreme views will ever be adopted for actual construction.

A practical point, which has been overlooked until lately in the

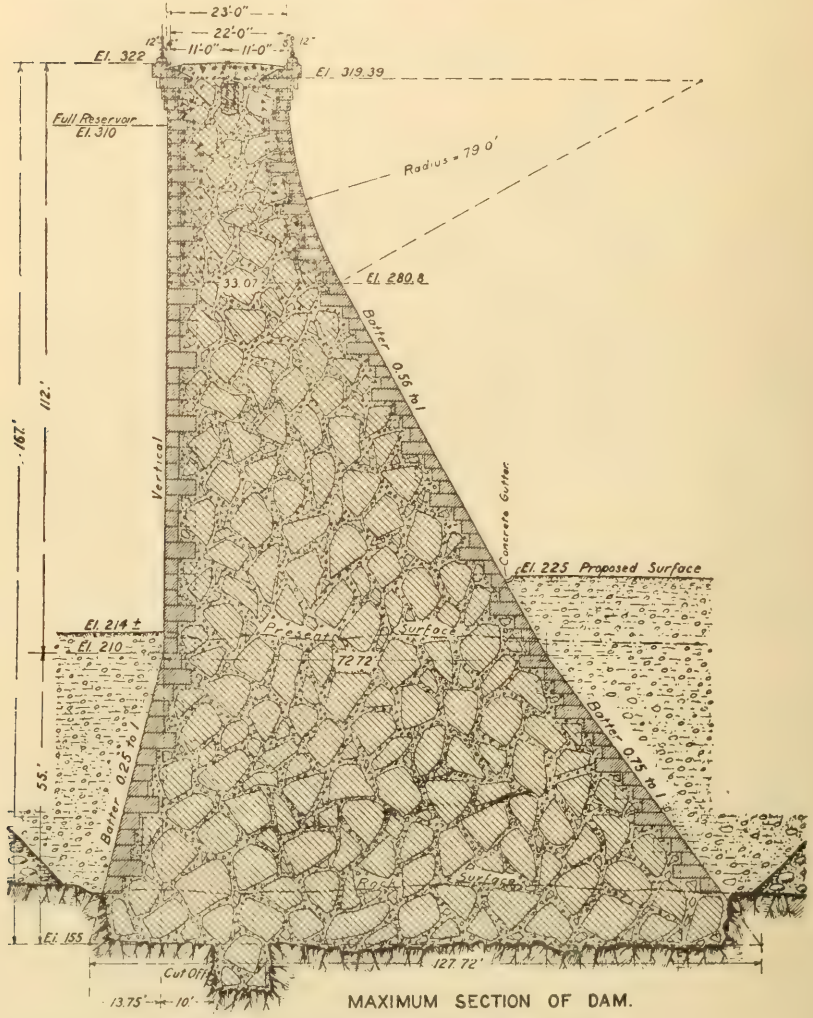


Fig. 18. Croton Falls Dam, New York

construction of masonry dams, is the provision of some kind of expansion joint in a dam to prevent the masonry from cracking when considerable changes of temperature occur. Observations made on the Boonton Dam, New Jersey, and the Croton Fall Dam,

New York, though not complete, indicate that there is very little change of temperature in the inner parts of a masonry dam, but that the faces are exposed to great temperature changes, varying from the cold of midwinter to the greatest heat of summer.

"Temperature cracks," some of them very fine will be found in most masonry dams. An attempt to prevent these cracks was made in the Croton Falls Dam, New York, by reinforcing the upper part of the masonry by $1\frac{1}{2}$ x $1\frac{1}{2}$ inch steel bars, as shown in Figure 18. The ends of the bars were turned at right angles. The different bars were laid carefully to line and were hooked tightly together, wedges being inserted at the joints when necessary.

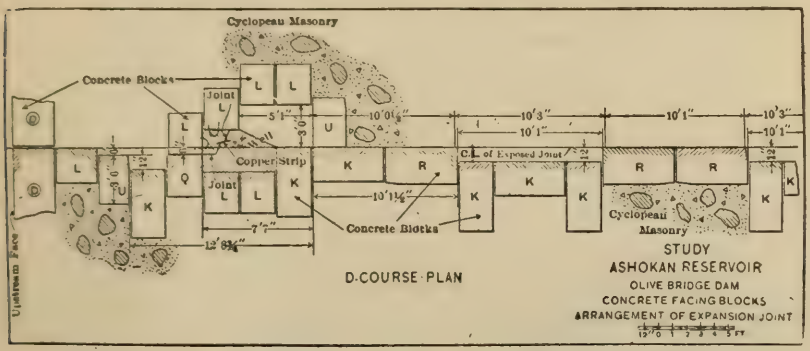


FIG. 19. EXPANSION JOINT OF OLIVE BRIDGE DAM

In spite of this expensive reinforcement some slight cracks occurred in the masonry of this dam.

In a masonry dam, 104 feet high and 500 feet long, which was recently built for the Tennessee Coal and Iron Company, a male and female expansion joint extending from the top of the dam to the bottom, was placed every 80 feet. These joints were filled with ordinary No. 6 paving pitch and proved to be absolutely water tight.[1]

To provide for expansion and contraction in the masonry, joints made as shown in Figure 19 were placed at intervals of 84 feet in the Olive Bridge Dam, recently built across Esopus Creek, New York. One side of the joint is made of concrete blocks which are coated at the joint with a lubricant to prevent the masonry on the other side of the joint from adhering to the blocks. If the offset and key formed by the concrete block do not prevent leakage, a copper strip will be inserted across the expansion joint in concrete

[1] See description of Mr. W. F. Wilcox in Trans. Am. Water Works Ass., for 1912, p. 111.

in the upstream portion of an inspection well that is to be provided at the joint. As a last resort, the whole inspection well can be filled with some elastic watertight material should this be necessary.

In the Olive Bridge Dam (Plate H) and in some other dams a system of drain pipes, leading to one or more drainage galleries (which may also be used for inspection) is built into the masonry

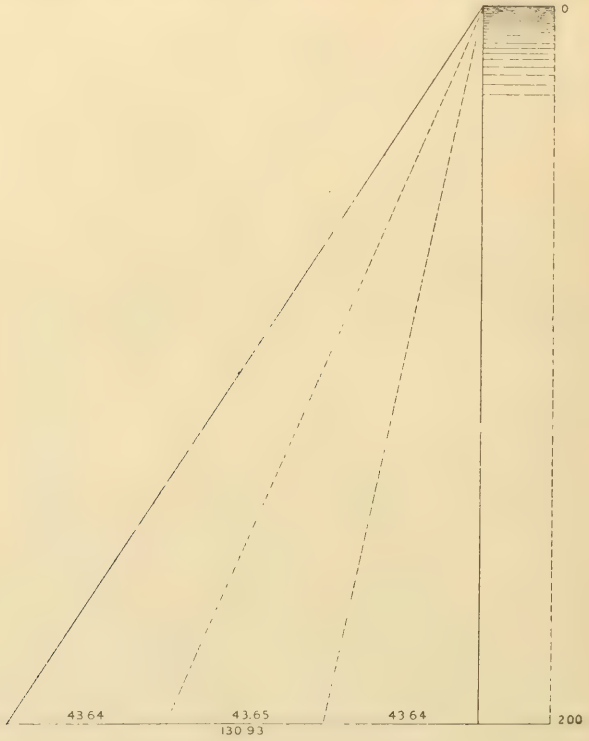


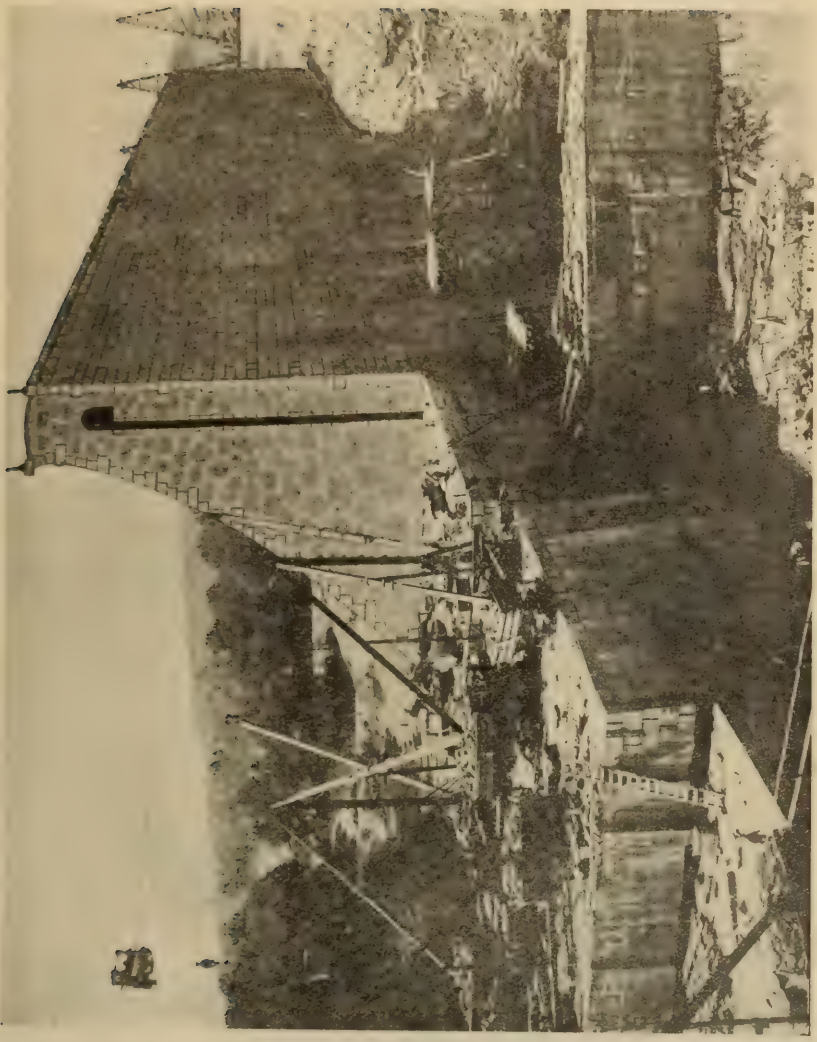
FIG. 20. TRIANGULAR PROFILE

to afford an outlet for all water that may percolate into the masonry. Some engineers think that such drainage systems induce leakage from the reservoir and do more harm than good.

In examining Figure 14 it will be seen how much the profile types advocated by different authorities differ from each other. In all of these types both faces are more or less battered, but the tendency has been to give more slope to the downstream face of a dam than to the upstream face.

For many years the writer has claimed that the correct profile

PLATE II



OLIVE BRIDGE DAM

for a masonry dam which has simply to resist the hydrostatic pressure of the water is a right angle triangle with its vertical side turned upstream.[1] The pressure of the water against the dam is represented graphically by a triangle and it seems rational that the masonry that is to resist this force should have a triangular profile (Fig. 20). The French engineers have generally designed the profiles of their masonry dams so as to have the maximum pressures at the faces at all levels, except near the top, equal the given limit of pressure. Such a profile they call one of "equal resistance." Near the top of these dams the pressures are naturally always less than the given limit of pressure.

To the writer it seems more logical to allow the maximum pressures at the faces of the dam to increase gradually from zero at the top until the given limit of pressure is reached. Below this level, the faces must be battered sufficiently to keep the maximum pressures just on the given limit. If we adopt 14 tons per square foot as the limit of pressure for the downstream face and 18 tons per square foot as the limit for the upstream face, the triangular profile shown on Figure 20, could be safely used for a height of 200 feet, if the lines of pressure for reservoir full or empty are kept within the center-third of the profile, so as to avoid tension in the masonry. Assuming the surface of the water to be at the top of the dam, the base of this profile is given by the simple formula:

$$x = \frac{d}{\sqrt{r}}$$

in which x = width of the base
d = depth of water
r = specific gravity of the masonry.

For a weight of masonry of 146 pounds per cubic foot, the width of the triangular dam would be about two thirds of the height.

To resist the shocks caused by waves or floating bodies a dam must always have a certain width at the crest. In many cases the dam must be made sufficiently wide on top to serve as a roadway. The exact width of crest for any given case must be determined by practical consideration. Having fixed the top width, the downstream face of the dam is kept vertical from the top down until it reaches the slope of the simple triangular profile (Fig. 21). The angle of intersection of the vertical and sloping part of the

[1] See page 3) of first edition of The Design and Construction of Masonry Dams, by Edward Wegmann. Published in 1888.

down-stream face should be rounded off, to improve the appearance of the dam.

The small inverted triangle of masonry which we have added to the simple triangular profile adds to the stability of the dam, and of the problem given is to find the profile of minimum area that will satisfy the given conditions, the weight of this small triangle of masonry must be taken into account. Including the weight in

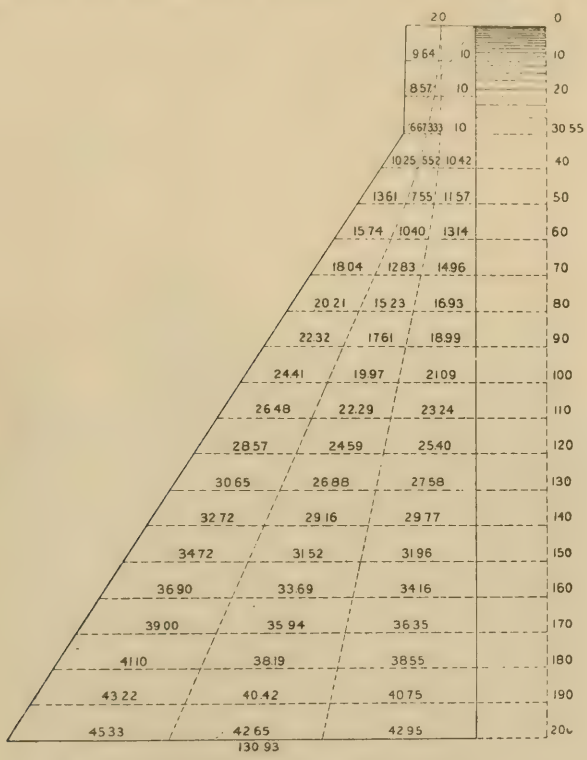


FIG. 21. PRACTICAL PROFILE-TYPE NO. 1

the calculations the profile becomes the one shown in Figure 22, which has about 5 per cent less area than the one shown in Figure 21. The latter is, however, generally to be preferred to the former on account of its simplicity.

The writer knows of no theoretical or practical reason why the simple profile shown in Figure 21 should not be adopted in the construction of the dam. It is an advantage, both theoretically and practically, to keep the upstream face vertical as far down from

the top as possible, i. e., until the limiting pressure is reached. The first dam in which this was done is the Medina Dam, recently built near San Antonio, Texas. In accordance with the writer's recommendation, the upstream face of this dam was made vertical for the whole height 165 feet.

There are a number of other interesting points that might be mentioned, but this paper has already become too long. The writer has attempted to review briefly the principal points connected with the design and construction of masonry dams and he must refer to books on dams for a fuller discussion of the subject.

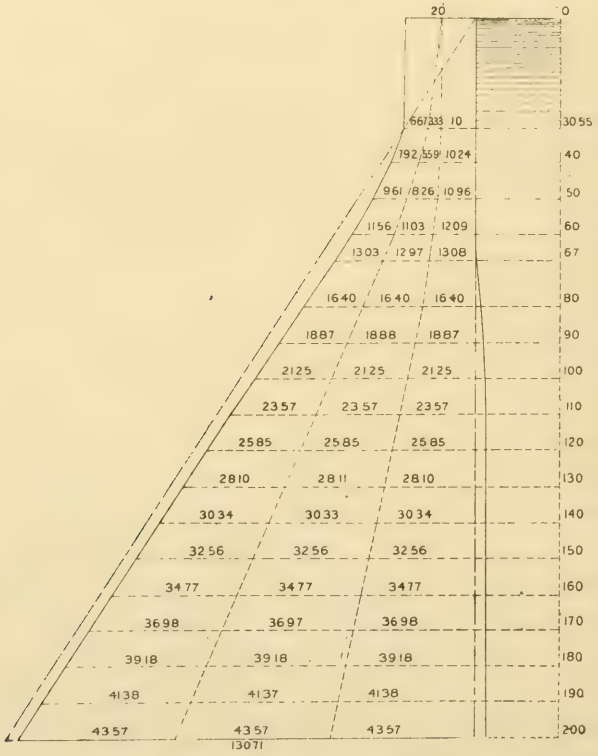


Fig 22. Practical Profile-Type No. 2

High Masonry Dams

(*Dimensions in Feet*)

DAM	LOCATION	DATE OF CONSTRUCTION	DEPTH OF WATER	HEIGHT ABOVE BED-ROCK	WIDTH		LENGTH ON CREST	PLAN
					TOP	BASE		
Alicante	Spain	1579–1594	127	135	65.6	110.6	190	Curved
Puentes[1]	"	1785–1791	154	164	35.7	144.3	925	Polygonal
Val de Infierno	"	1785–1791	.....	116	41.1	137.0	330	"
Zola	France	About 1843	120	123	19.0	41.8	205	Curved
Lozoya	Spain	1852	94	105	22.0	128.0	238	Straight
Furens	France	1862–1866	164	171	9.9	161.0	328	Curved
Ternay	"	1865–1868	113	125	13.1	81.7	.....	"
Habra[2]	Algiers	1865–1873	117	125	14.1	95.0	1476	Straight
Ban	France	1867–1870	138	157	16.4	127.0	.....	Curved
Gileppe	Belgium	1869–1875	148	154	49.2	216.5	771	"
Villar	Spain	1870–1878	162	170	14.8	154.5	546	"
Pas du Riot	France	1872–1878	.....	113	.....	.....	.....	"
Poona	India	.....	.....	108	13.8	60.8	5136	Polygonal
Hijar	Spain	1880	.....	141	16.4	147.0	236	Curved
Gorzente	Italy	1880–1883	121	126	13.1	99.6	492	"
Lagolungo	"	About 1883	.....	144	16.4	.....	.....	.....
Gran Cheurfas	Algiers	1882–1884	.....	131	13.1	134.5	509	Straight
Hamiz	"	1885	115	135	16.4	91.2	532	"
Vyrnwy	England	1882–1889	.....	146	20.0	117.8	1350	"
Tansa	India	1886–1891	.....	118	12.0	100.0	8800	.....
San Mateo	United States	1887–1889	.....	170	20.0	176.0	700	Curved
Tache	France	1888–1892	.....	161	13.1	.....	.....	"
Bhatgur	India	.....	.....	130	12.0	74.0	4067	.....
Beetaloo	"	1888–1890	.....	110	14.0	110.0	580	Curved
Periar	"	1888–1897	.....	180	12.0	136.0	1200	Straight
Mouche	France	About 1890	95	101	11.5	.....	1346	"
Lagrange	United States	1890	.....	125	24.0	90.0	320	Curved
Titicus	" "	1890–1895	.....	135	18.0	75.0	534	Srtaight
Hemmet	" "	1891–1895	.....	136	10.0	100.0	.....	Curved
Butte City	" "	1892	.....	120	10.0	83.0	350	"
New Croton	" "	1892–1907	150	297	22.0	206.0	2168	Straight
Echapre	France	1894–1898	116	121	17.0	88.6	541	Curved
Cotatay	"	1900–1904	121	144	16.2	.....	509	"
Lake Cheesman	United States	1900–1904	.....	232	18.0	176.0	.....	"
Spier Falls	" "	1900–1905	80	154	.....	.....	1369	Straight
Boonton	" "	1900–1905	105	114	17.0	77.0	2150	"
Wachusett	" "	1900–1906	.....	228	25.8	187.0	1476	"
Ondenon	France	1901–1904	107	123	15.4	93.8	420	Curved
Urft	Germany	1901–1904	.....	190	18.0	165.7	1037	"
Komotau	Austria	1901–1904	.....	139	13.1	98.4	509	"
Cher	France	About 1907	.....	154	15.4	141.1	323	"
Cataract	Australia	1902–1908	150	192	16.5	158.0	811	Straight
Roosevelt	United States	1905–1911	240	280	16.0	170.0	1080	Curved
Pathfinder	" "	1905–1910	.....	206	10.0	94.0	425	"
Shoshone	" "	1905–1910	.....	324	10.0	108.0	200	"
Cross River	" "	1905–1909	106	170	23.0	116.3	772	Straight
Croton Falls	" "	1906–1911	97	173	23.0	127.7	1100	"
Olive Bridge	" "	1907–1913	210	252	26.33	200.0	1000	"
Assuan Dam	Egypt	Raised 1907–1911	82	112	36.0	.....	6200	"

[1] The Puentes Dam was ruptured on April 30, 1802. [2] The Habra Dam failed in December, 1881.

FILTERS FOR THE TORONTO WATER SUPPLY

By Francis F. Longley

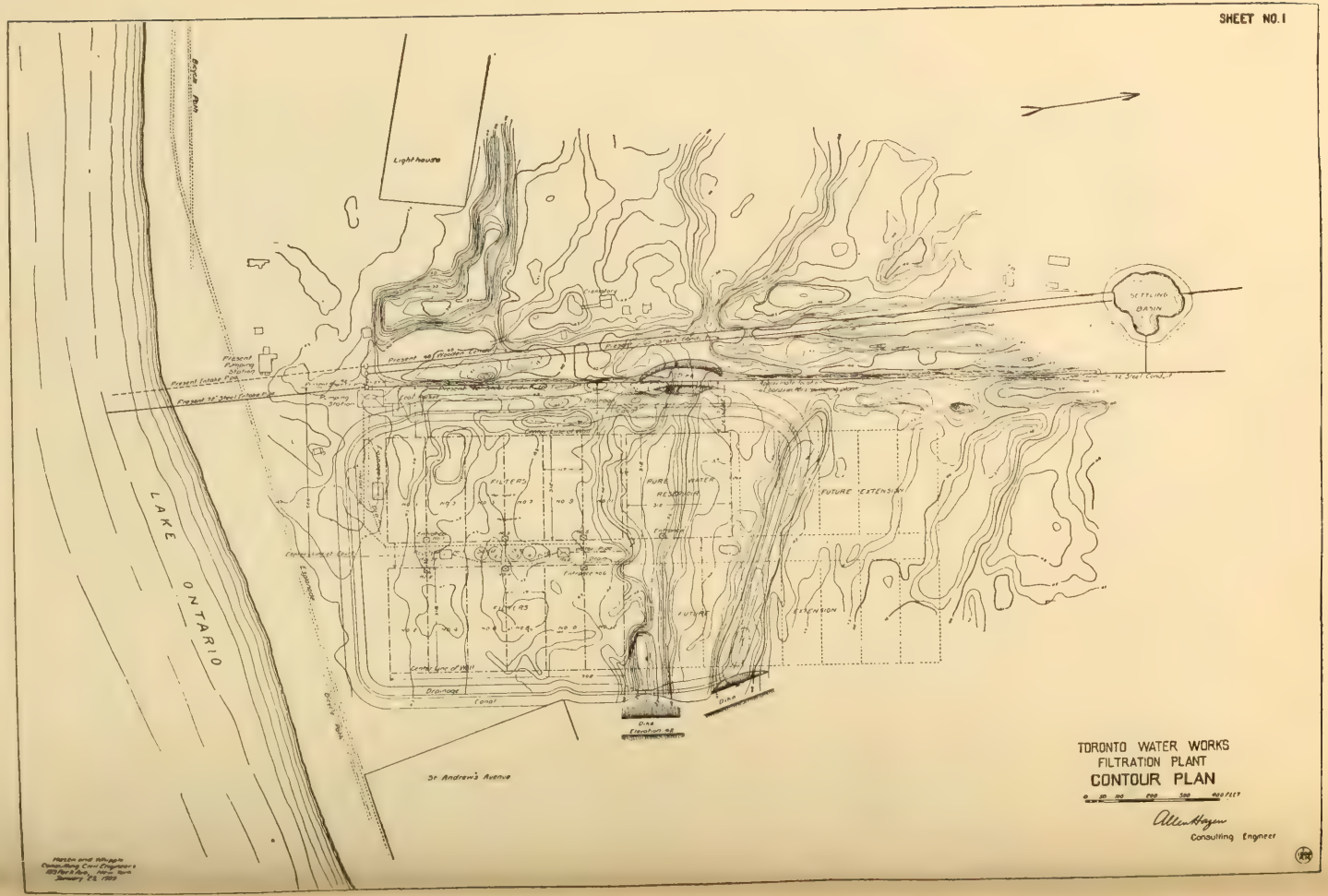
The City of Toronto has recently completed the construction of a sand filtration plant for the purification of its water supply. Like many other cities on the Great Lakes, its supply is taken from the lake into which the sewers of the city flow. Some years ago the people of Toronto began to appreciate the fact that this was not a safe and wholesome condition of affairs, and consequently they took action which resulted in the construction of the plant herein described.

An appropriation for this work was made in 1908. Messrs. Hazen and Whipple were called in to prepare plans for the work and contracts were let in May, 1909.

The plant, in a general way, follows the design so successfully carried out at Washington, D. C., which plant the writer described before this Association several years ago (Proceedings 1908, p. 590). It consists essentially of twelve filters, a pure water reservoir, a low lift pumping station, an office and laboratory building, and the pipe lines and other accessories which go to make up a complete plant.

The intake pipe, which was in place and in use before this work was started, comes in from a point about a half mile out in the lake, runs generally northward across the Island, which lies along the outer edge of Toronto harbor, thence through a tunnel under the harbor to the main pumping station in the city. For obvious reasons the main lines of the filter plant were laid out parallel to this 6 foot steel pipe across the Island, as shown on the Contour Plan of the works, Sheet No. 1. The water enters the plant at the low lift pumping station which adjoins a crib structure some five or six hundred feet from the lake shore. The pumps lift the water into the main raw water pipe, which carries it to the filters. From the filters the water flows through the cast iron effluent pipes to the two regulator houses, and thence through another large concrete pipe line to the reservoir. The outlet of the reservoir connects directly by a concrete pipe with the 6 foot steel pipe before men-

SHEET NO. 1



TORONTO WATER WORKS
FILTRATION PLANT
CONTOUR PLAN

0 20 60 100 200 400 FEET

Allen Hazen
Consulting Engineer

Hazen and Whipple
Consulting Civil Engineers
Nov. York
January 23, 1909

tioned, which brings the water back to the same line through which it flowed before the plant was built.

Practically all of the bottom of the masonry work of the plant was below lake level. In order to avoid the difficulty of continuous trouble with water, a comprehensive scheme of drainage was arranged, consisting of a canal which was excavated around the entire site of the filters and reservoir. At the points where this canal crossed old lagoons or channels, dikes of sand were thrown up to make the canal entirely enclosed. A temporary pumping station was then erected on the bank of the canal and the water pumped out until it stood at a level considerably below lake level, upon which the ground water level within the canal, of course, fell and remained at approximately the same low level. This permitted

Drainage Canal During Excavation

the excavation and the placing of almost all of the masonry and pipe lines to proceed without any interference from water. At a few points where isolated structures or pipe lines were especially low, special means for local drainage were required.

Much lack of confidence was expressed among contractors and other observers before the work started, that we would not be able to pump the water out of this canal, which had a total length of over 4000 feet, as its proximity to the lake and the sandy nature of the material made it appear that the quantity which would flow into the canal through the sand would be enormous. An estimate of this was made, however, when the scheme was first considered and the engineers, in writing the specifications, indicated to the contractor the pump capacity for the canal pumps. Two 12 inch centrifugal pumps were specified and the city guaranteed to protect

the contractor in case these pumps were not adequate for the purpose. They were ample, however, and no trouble of any kind was met with in keeping the water at a sufficiently low level continuously throughout the period from about October, 1909, to November, 1911.

PUMPING STATION

The pumping station consists of a massive concrete substructure, which serves as a pump well, and which, as before stated, immediately adjoins a steel crib on the intake pipe line. The upper part of this pump well is built of reinforced concrete in the form of a large tank or upper well supported over the lower, and this receives the discharge from the low lift pumps. From this upper well a

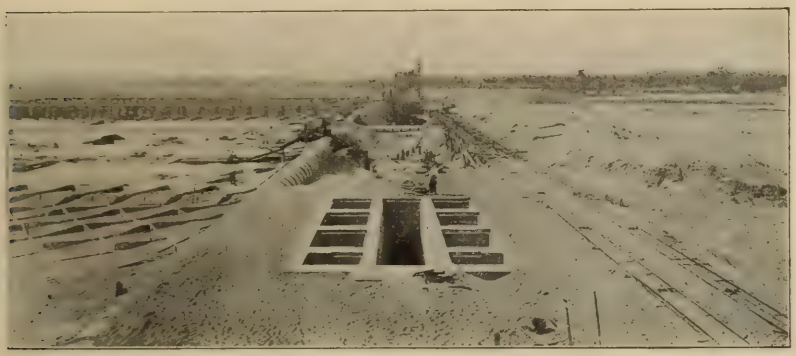
Drainage Canal Completed and Water Drawn about 8 Feet Below Lake Level

6 foot concrete pipe runs directly to the central court, from which it branches to the several filters. A connection was also left in this well for the future extension of a second pipe.

The main power for the plant is electrical. The main pumping units are vertical screw pumps, which were designed in the office of Hazen and Whipple. This type of pump seemed more easily adapted to the requirements of the service than any other type of equipment then available. Each pump consists essentially of a screw somewhat similar to the propeller of a ship, which is set on a vertical shaft below the water line within a vertical tube, and to the top of this shaft is coupled an induction motor, also set vertically. When the pump is started the action of the screw lifts the water, and it discharges to the side at the top of the shaft through an opening controlled by a rectangular sluice gate. This pump is

a comparatively new type, but has given good service on this work. A steam auxiliary was provided in a single large centrifugal pump the suctions of which dipped down into the same suction well and discharged into the same upper well.

The screw pumps have a total capacity of 50 million gallons or more and the steam pump about the same if operated independently. The pumping station contains also two pumps for supplying water for the sand washers. These are 8 inch centrifugal pumps driven by constant speed induction motors. They discharge through a 10 inch cast iron pipe which runs out through the central court. The station contains also a pump on the main drainage system. This is a 12 inch centrifugal pump driven by an electric motor, and



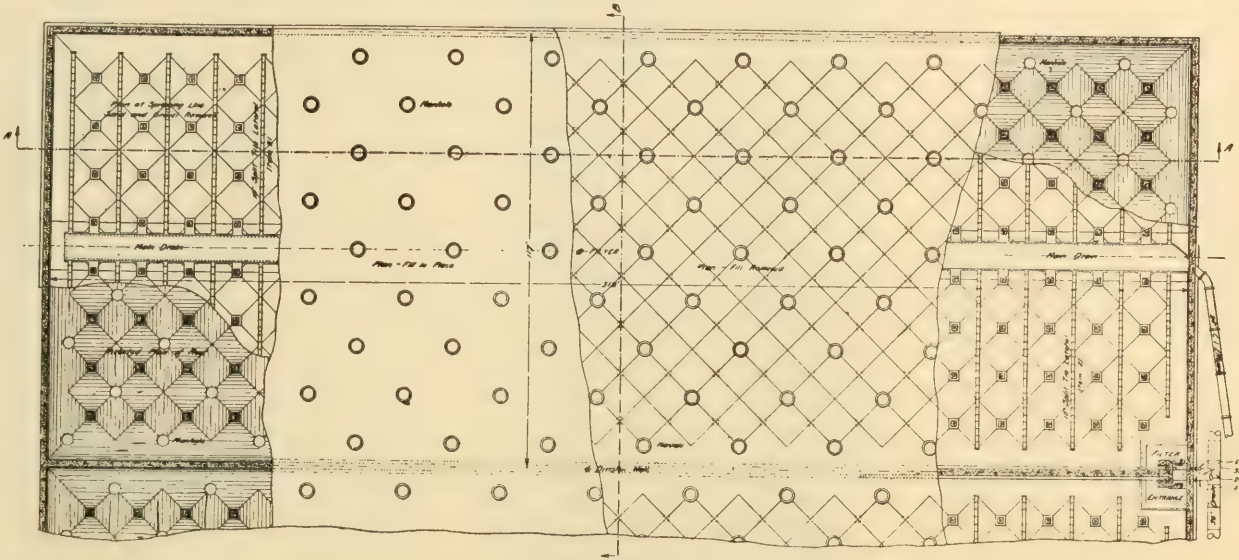
CENTRAL COURT SHOWING SUBSTRUCTURE OF REGULATOR HOUSE, CONCRETE PIPE LINES, EXCAVATION AND FORMS FOR SAND BINS, ETC.

is designed to lift the water flowing in the main drain of the plant the few feet that are necessary to bring the drainage above lake level. The station contains also the necessary boiler plant, coal pocket, switchboards, etc.

The filters are laid out in two rows of six filters each, arranged along a central court which is 74 feet in width. In this central court are located the sand bins, the regulator houses, the raw water and pure water pipe lines, the sand washing system, the drainage system, electric light ducts, etc. The pure water reservoir is located just north of the westerly row of filters.

Each filter has an area of 0.8 of an acre, giving a total area of 9.6 acres. The rate of filtration assumed in the design was 6 million United States gallons, or 5 million Imperial gallons per acre per day. Each filter in operation at the full rate should therefore de-

SECT. A-A.



PLAN
FILTER No. 2

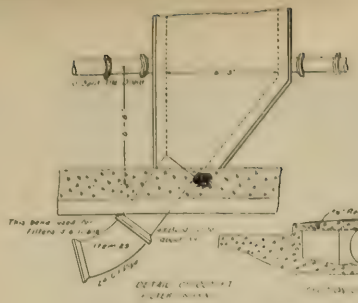
SECT. B-B.

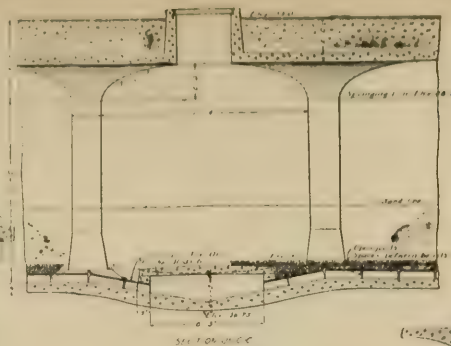
TORONTO WATER WORKS
FILTRATION PLANT
GENERAL PLAN
FILTERS

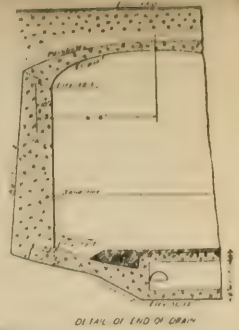
0 5 0 10 20 30 40 FEET

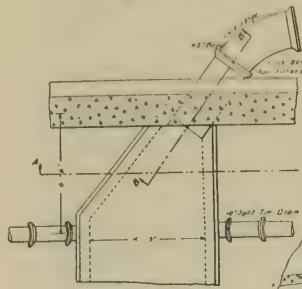
Allen Hazen
Consulting Engineer

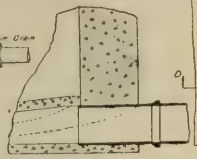
Fenn and Wright
Consulting Civil Engineers
45 Park Ave., New York
January 23, 1940

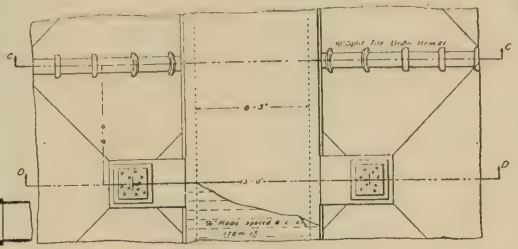


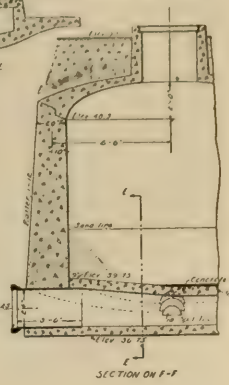


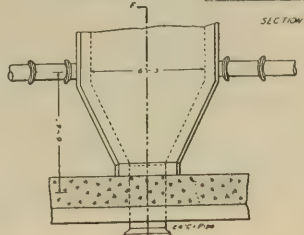


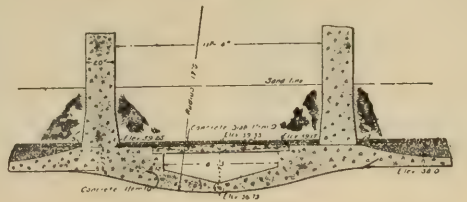












TORONTO WATER WORKS
FILTRATION PLANT
FILTER DETAILS
MAIN DRAIN

0 1 2 4 6 FEET

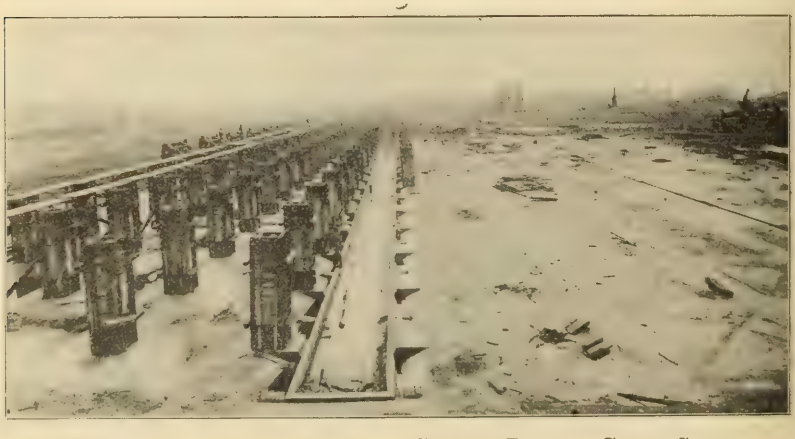
Allen Hazen
Consulting Engineer

Hazen and Whipple
Consulting Civil Engineers
42 Pine Ave. New York
January 23, 1919

General View Showing Various Steps in Progress of Filter Masonry Construction

liver 4 million Imperial gallons per day, and the entire plant 48 million. For conditions such as exist in Toronto, the available capacity of the system to cover maximum draft should exceed the safe annual average capacity by 50 per cent. On this basis the safe annual average capacity of this plant is 32 million gallons per day.

The filter masonry is built with a floor of inverted groined arches of concrete (Sheet No. 10). On the high points of these inverted arches are built piers, and walls along the sides, and a roof of groined arches is supported thereon. The entire filter is covered with a fill 2 feet in depth, and manholes extend upwards through this fill from the interior of the filter to a point 6 inches above the finished surface. Lengthwise through the center of each filter extends a



Filter Floor and Main Drain Before Placing Cover Slab

FILTER READY FOR PLACING CONCRETE ROOF VAULTING, SHOWING MAIN DRAIN COVERED WITH REINFORCED CONCRETE SLABS

PLACING GROINED ARCH ROOF VAULTING

INTERIOR OF FILTER WITH FORMS PARTLY REMOVED

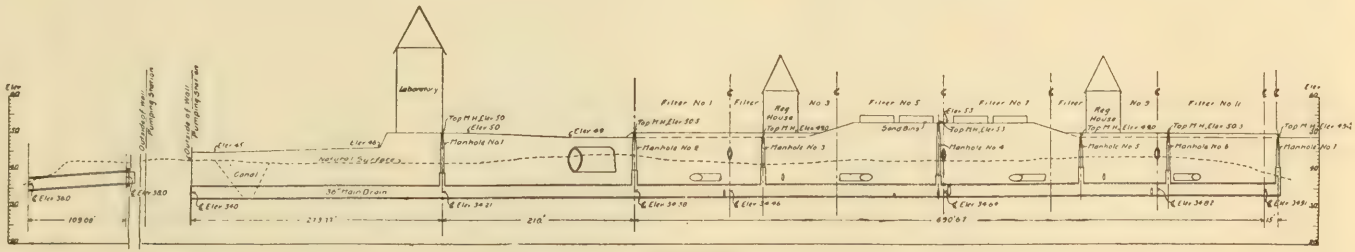
INTERIOR OF FILTER SHOWING SPLIT TILE UNDERDRAINS AND FILTER GRAVEL

channel formed in the concrete floor and covered with a reinforced concrete slab, which serves as the main underdrain for the filter (Sheet No. 12). Laterals of split tile pipe are laid on the floor across the filter between each two rows of piers, running into the central drain. Over the tops of these laterals is laid the filter gravel, which consists of 7 inches of stone or gravel from one to two inches diameter, 2.5 inches of stone or gravel from $\frac{3}{8}$ inch to 1 inch, and 2.5 inches less than $\frac{3}{8}$ inch and coarser than sand. Upon this is placed the filter sand to an average depth of 3.5 feet.

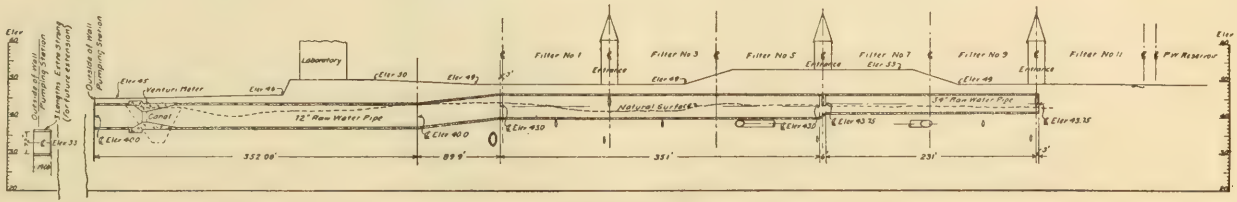
HANDLING NEWLY MADE SECTION OF 72-INCH CONCRETE PIPE

The entrance to the filter is through a house at one of the front corners of the filter, a single house serving as the entrance to two adjoining beds. Within this entrance house are located also the inlet gates, which control the flow of raw water into the filter, and the drain gates, through which the water can be discharged into the drainage system from above the surface of the sand. The effluent gate of each filter is in the regulator house.

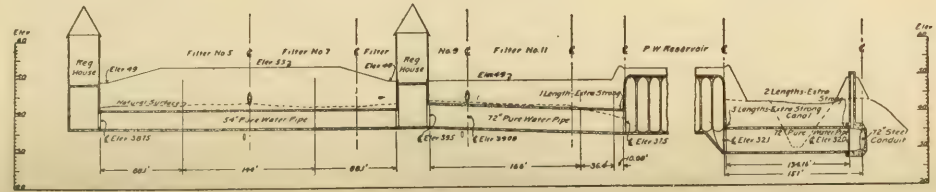
The raw water is conveyed from the pumping station to the filters through a concrete pipe. Pipe of similar design are used also for the pure water carrier and for the main drain. This pipe was made in three sizes, 72 inches, 54 inches and 36 inches in diameter.



36" MAIN DRAIN



54" AND 72" RAW WATER PIPE



54" AND 72" PURE WATER PIPE

TORONTO WATER WORKS
FILTRATION PLANT
CONCRETE PIPE
PROFILES

Allen Hazen
Consulting Engineer

Hazen and Whipple
Consulting Civil Engineers
143 Main Ave., New York
January 21 1913

General View of Concrete Pipe Yard

The original designs were made in the office of Messrs. Hazen and Whipple, but contractors were invited to submit alternative designs with their tenders if they so desired. On this basis the successful contractor arranged to have these pipes made, and the work was done right on the filter site. The pipes and thicknesses are as follows:

72 inch	7 inches thick
54 inch	5.5 inches thick
36 inch	4.0 inches thick

The pipes were cast in lengths of 4 feet each. They were reinforced with a combination of metal mesh and steel rods which is

Placing 72-inch Concrete Pipe at Outlet of Pure Water Reservoir

arranged within the pipe in an elliptical shape, with its longest axis horizontal in order to develop the maximum strength under load. Short lengths of pipe 13 inches long, designated as stubs, were also made to form the connection between the pipe lines and the various masonry structures. Where a pipe line was to enter a structure one of these stubs was cast right into the wall, thus forming a convenient starting point for laying the pipe, and also providing a plane of cleavage close to the wall, in case of unequal settlement between the pipe and the structure.

The pipes were carried from the pipe yard to the trench by rolling. At the trench they were handled by means of a derrick. Each pipe was laid, supported upon two pieces of stout planking and

Concrete Raw Water Pipe Showing also Typical Manhole Construction of 36-inch Concrete Pipe

brought to line and grade. The specifications provided that the dovetailed joint on the inside of the pipe was not to be filled with mortar until after the pipes had been loaded with water for a period of a week, in order to attain as much as possible of their maximum settlement. As a general thing, this meant the postponement of the inside joint work until after the trenches had been filled, and much other work completed. In order, therefore, to prevent sand and also water, as far as possible, from entering the joints before and during the finishing of them on the inside, a cover was put around the outside of each joint consisting of several layers of tar paper and tar, all covered with a strip of burlap and bound with a wire a few inches each side of the joint to hold it snug against the pipe. This procedure gave results which were very satisfactory.

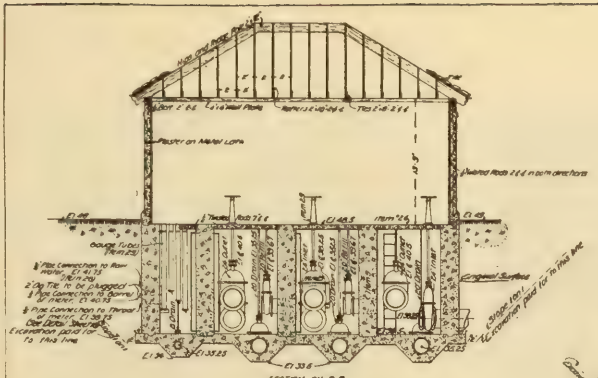
As before stated, the raw water pipe is of this type. Its diameter from the pumping station to the middle of the central court is 72 inches (Sheet No. 19). From that point to the north end of the court it is 54 inches. Branches 36 inches in diameter extend from this main line to the filter entrances.

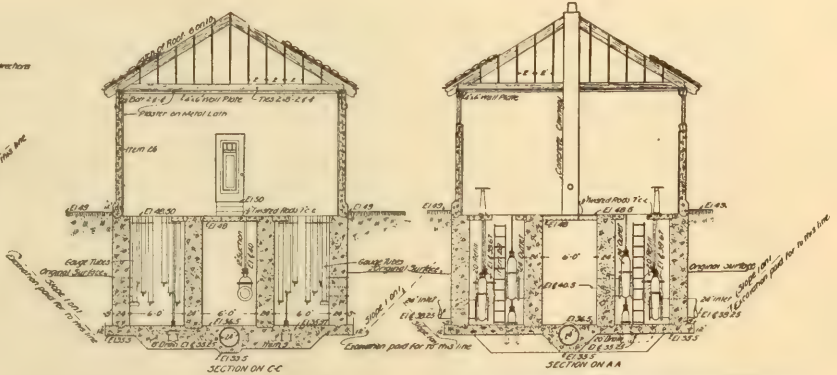
From the front end of the main underdrain of each filter a cast iron pipe extends under the court to one of the two regulator houses. On each of these cast iron effluent pipes, which are 24 inches in diameter, is a Venturi meter which shows on an indicating device in

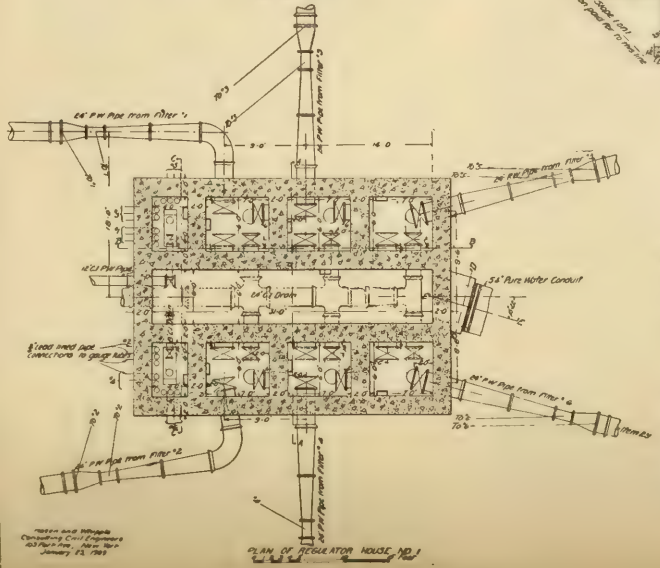
Pure Water Reservoir Masonry Ready for Placing Groined Arch Roof

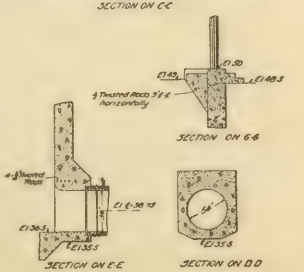
the regulator house the rate of flow from each filter. In each regulator house are the effluent wells and controlling gates for six filters (Sheet No. 15). Also, the arrangements for backfilling the filter after cleaning, and for drainage, etc. From the first regulator house a 54 inch concrete pipe of the design already described, extends northward to the second regulator house, and thence as a 72 inch pipe to the pure water reservoir. This reservoir is similar in general design to the filter masonry, excepting that the floor is four feet lower than the filters, and the roof one foot lower. The reservoir has a capacity, when full, of 7.5 million Imperial gallons.

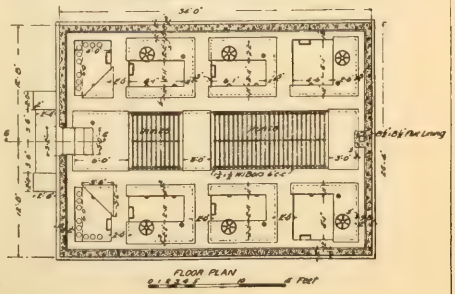
In the northwest corner of the reservoir is a depressed section

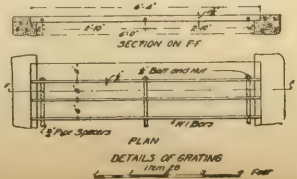








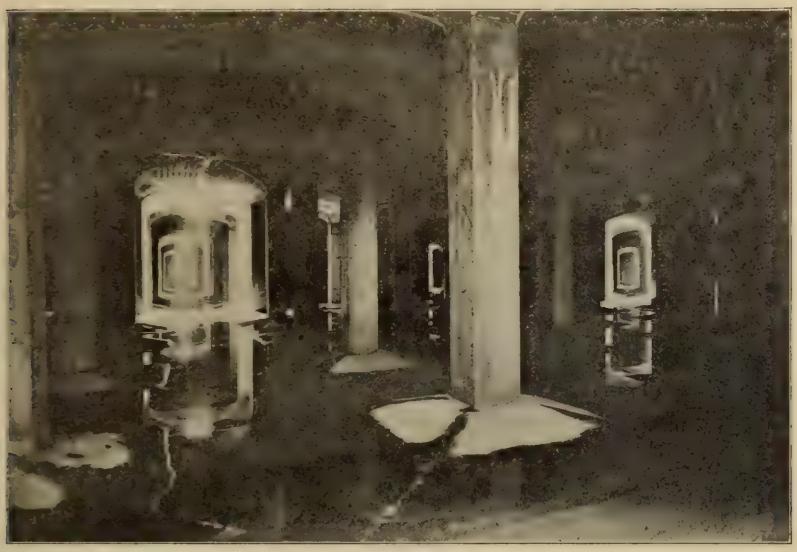




TORONTO WATER WORKS
FILTRATION PLANT
REGULATOR HOUSE
SUB-STRUCTURE

Allen Hazen
Consulting Engineer

of the floor, from which a 72 inch concrete pipe leads a short distance to the 72 inch steel pipe (Sheet No. 19) which has been in use for several years carrying the main supply from the lake to the city. Towards the end of the work a connection had to be made between this concrete pipe and the steel pipe. This presented some difficulties owing to the fact that the flow through the steel pipe could not be interrupted with comfort and safety to the city for more than a few hours at a time. The concrete pipe was laid up to within a few feet of the steel pipe. A suitable excavation was



Interior View of Pure Water Reservoir

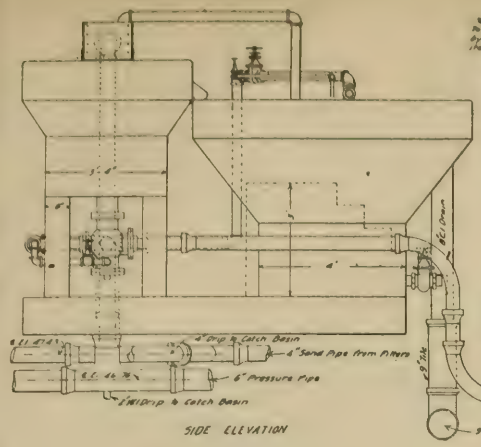
then made entirely around and under the steel pipe, and a massive block of concrete well reinforced was built surrounding both the steel pipe and the end of the concrete pipe, the bore of the concrete pipe extending through this monolith right to the steel pipe. When other preparations were made for turning filtered water into the city, the final step, therefore, consisted in cutting out the side of the steel pipe some 35 square feet in area, which was exposed on the inside of this structure. This was done by means of the oxy-acetylene flame.

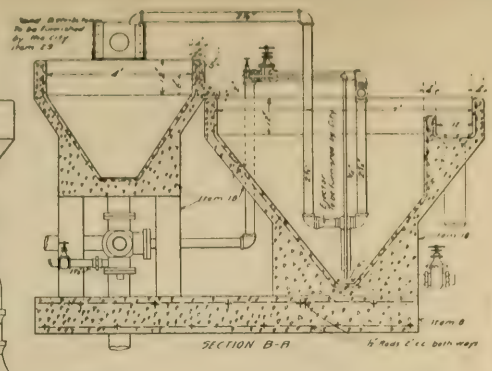
Two periods of night work were required to accomplish this. It required the unwatering of about a mile of 72 inch steel pipe and the maintenance of the supply to the city during the interval from

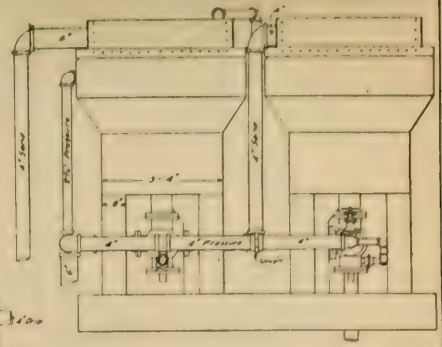
the high level reservoir, which, under the conditions that then existed, had an available capacity of only a few hours supply. On both nights the unwatering of the 6 foot steel pipe commenced at about 6.30 p. m., and its refilling, after the operations inside of the pipe, at about 6 o'clock the following morning. Out of these two periods the effective time available for actual work was between nine and ten hours, and this sufficed to remove the steel plate and to put the connection in final condition so that the entire supply to the city could be put through it.

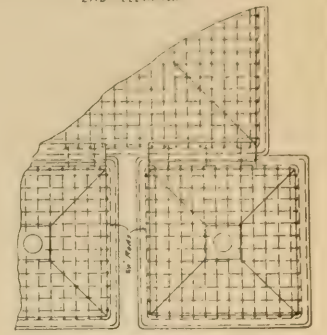
One of the most important parts of the maintenance of a filter plant of this type is the sand handling. The sand washer pumps in the pumping station have already been mentioned. They deliver water into a 10 inch cast iron main which runs throughout the length of the court. Five inch branches from this main run along each filter wall. Along each wall there is also a 4 inch wrought iron pipe which serves as the discharge line from the filters to the sand washers. There is a sand washer located in the center of the court opposite each filter wall. A system of 4 inch cast iron pipe connects these sand washers with each other, and with the four sand bins, and also for the purpose of resanding with the 4 inch wrought iron pipes along the filter walls already described. The hydraulic method of transportation is used and the design follows, in a general way, the design used at Washington and Springfield. The ejector for removing the sand from the filter consists of a rectangular steel box containing, at the bottom, the nozzle and throat which form the ejector proper, and irrigator pipes whose function is to keep the sand in a saturated condition about the jet. On one end of the box on the pipes which lead to the jet and from the throat, are suitable hose connections, so that the box may be hooked up to the pipe lines along the side wall of the filter by means of 50 foot lengths of flexible hose.

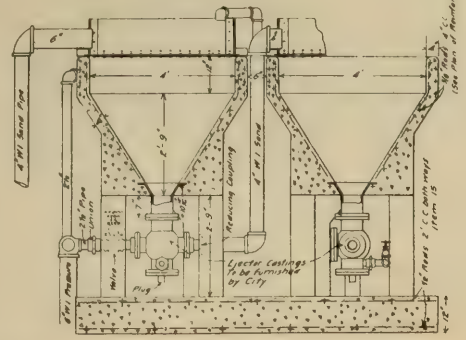
The sand washers in the court consist of three reinforced concrete hoppers (See Sheet No. 25), the smaller two of which are used for the actual washing process, and the third and larger one for the recovery of the sand that tends to overflow. In the bottom of each of the washer hoppers is an ejector consisting of jet and throat suitably designed, and also a connection, called the irrigator, through which clean water can be supplied. The mixture of dirty sand and water is sent out of the filter by the ejector, discharging into the first of these washer hoppers. The agitation it receives is violent enough to separate the mud from the sand and as the slush

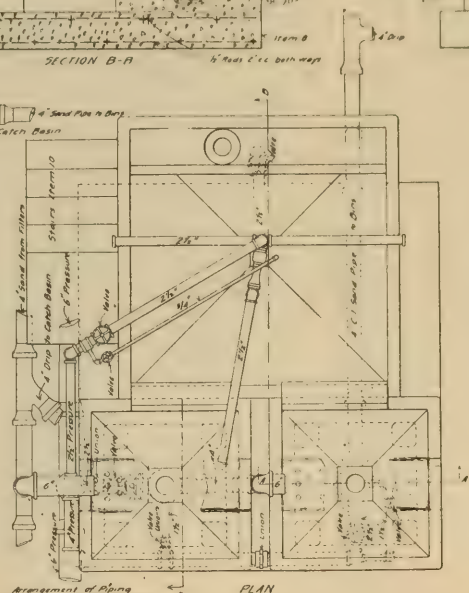

4" Drip to Catch Basin
4" Sand Pipe from Filters
6" Pressure Pipe
2" W.I. Drip to Catch Basin
SIDE ELEVATION
C.I. and W.I. Pipe included in Item 19










Item 19
4" Drip to Catch Basin
9" Drain to Catch Basin Item 22
4" Sand Pipe from Filters
4" Drip to Catch Basin
4" Pressure
4" C.I. Sand Pipe
Note: Arrangement of Piping may be changed to suit location
PLAN

TORONTO WATER WORKS
FILTRATION PLANT
SAND WASHER

0 .25 1 2 3 FEET

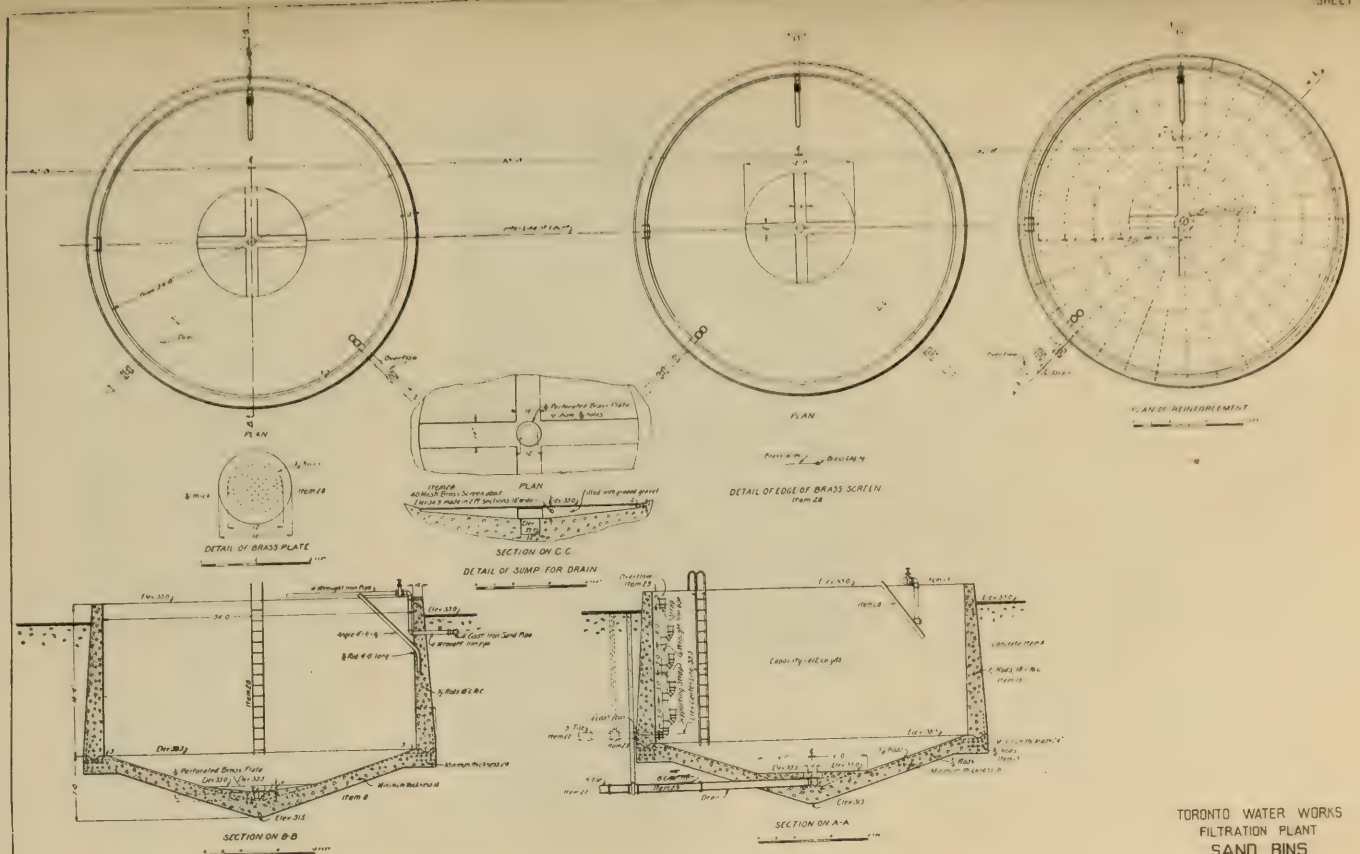
Allen Hazen
Consulting Engineer

Mason and Whipple
Consulting Civil Engineers
83 Park Row New York
January 23, 1909

falls into the washer hopper, the sand tends to fall to the bottom where it is continuously picked up and carried away by the ejector. A jet of water is introduced through the irrigator, which is just sufficient to give a vertical velocity in the water which will carry the muddy water out at the overflow lip and still permit the sand to settle to the bottom. The ejector in the first hopper carries the sand to the second hopper where the process is repeated. From the second hopper the ejector carries the now thoroughly clean sand to one or another of the four sand bins. The muddy water from the two washer hoppers overflows into the larger hopper above mentioned, which serves as a catch basin, arresting the sand which may come over and permitting the dirty water to flow away at an overflow into the drainage system.

The sand bins have a diameter of 34 feet and a depth of approximately 16.5 feet, giving a capacity of about 600 cubic yards. They are depressed below the surface of the ground (See Sheet No. 24). In the bottom of each bin is an arrangement consisting of a perforated plate covered with gravel and brass screens, and connected with a pipe leading to the drainage system which is designed to drain the water from the sand if required. With the method of handling the sand which has been permanently adopted, this bottom drainage, however, is not necessary. After these bins are filled from the washers and when a filter is to be resanded, an ejector of large capacity which is connected up with the pipe lines which lead back to the filters, is put down into the bin. This ejector is made up in very compact shape without any surrounding box, and is simply allowed to work its way down into the sand in the bin as far as it will, where it works away, taking out the sand until a huge crater is formed over it, after which it is lifted and moved to another part of the bin. Within the filter the sand is distributed as follows:

The filter is first filled with water to just the depth required for the new sand surface, and this level is maintained throughout the whole procedure. A small boat is fitted up with a pipe, having at one end a hose coupling for connection with the sand pipes along the wall, and at the other end a flaring discharge by means of which the incoming sand is spread. An attendant working in high boots and standing on the sand, keeps this boat continually moving as the refilling progresses, and the constant water level shows him when he has filled enough at any point. After sufficient sand has been put back in the filter in this way, the dirty water is flushed from



TORONTO WATER WORKS
FILTRATION PLANT
SAND BINS

Allen Hazen
Consulting Engineer

Hazen and Whipple
Consulting Civil Engineers
123 Pearl Ave. New York
January 23, 1909

the surface, the sand leveled off, after which the filter is ready for putting in service.

The dirty water from the sand washer system and also drainage water from the filters are carried away through a 36 inch concrete drain (Sheet No. 19) which runs lengthwise of the court and into the drainage well in the pumping station, in which is located the drainage pump already mentioned. Beyond the drainage well this pipe runs at a somewhat higher elevation and finally discharges into a lagoon. which lies to the west of the plant and connects with the bay but not directly with the open lake.

Office and Laboratory Building

The office and laboratory building is built entirely of reinforced concrete. It is a two story and basement structure and serves not only as an office and laboratory, but also, on account of the isolation of the works on an island two miles from the city, as the residence for the superintendent of the plant, a laboratory force, consisting of a bacteriologist, a chemist, and helpers maintaining constant supervision over the quality of the water and the operation of the system.

At the time the plant was designed in the fall of 1908, the water consumption of the City of Toronto was about 28 million gallons

per day, and there was nothing in the records to indicate an abnormal increase in the rate of consumption. As already stated, the plant was designed for a safe annual capacity of 32 million and a maximum capacity of about 48 million Imperial gallons per day. The years since 1908, however, have shown a remarkable increase in the amount of water pumped, the average daily consumption for the year 1912 having been 45 million gallons. The plant was put in service in January, 1912, and it is obvious, therefore, that its capacity has been taxed almost to the limit throughout the first year of operation. The seriousness of this condition has been recognized and the city has voted money for increasing the filtering capacity. In spite of this excessive draft the plant has given most excellent results. In time of storm in somewhat more than a year of operation, samples of raw water have sometimes been observed which have had turbidities as high as 700. The filtered water, however, has shown maximum turbidities no higher than 6 and average daily turbidities not exceeding 2. The bacterial condition of the raw water indicates clearly that it is not safe to use continually without treatment. The bacterial counts run up enormously high at times reaching maximums in the neighborhood of 175,000 and reaching monthly averages of 18,000. The average bacterial count in the filtered water during the past six months, more or less, has been about 100, and B. coli, which is commonly present in the raw water in 1, and even 0.1 cc., has not been detected in the filtered water in 1 cc., since April, 1912. This is a very creditable showing for a plant that is operating some 40 per cent in excess of the capacity for which it was designed.

The following is a summary of the cost of the work:

12 filters complete	$545,907.50
Pure water reservoir, complete	72,622.00
Pumping station and equipment	90,920.70
Engineering and inspection	72,069.00
Total cost of work	$781,519.20

Approximately $24,750 of this total is fairly chargeable to other work which was done in connection with filtration construction, but which does not strictly belong to it, and for which no special funds were provided. The total net cost was, therefore, about $757,000.

Area of filters, 9.6 acres.
Cost per acre for filters, $58,000.
Capacity of pure water reservoir, 15 million Imperial gallons.
Cost per million gallons for reservoir, $9,700.

Cost of Operation per Million Imperial Gallons Filtered

MONTH	OFFICE AND LABORATORY	LOW LIFT PUMPING TO THE FILTERS	FILTER CLEANING AND SAND HANDLING OPERATIONS	CARE OF GROUNDS AND MISCELLANEOUS	TOTAL COST PER MILLION GALLONS	
					Filtering	Filtering and Pumping
1912						
Jan.	$0.373	$2 064	$0.383	$0.170	$0.926	$2.990
Feb.	0.362	1.792	0.441	0.158	0.961	2.753
March	0.457	1.876	0.625	0.176	1.258	3.134
April	0.488	1.673	0.458	0 2 5	1.151	2.824
May	0.435	1.487	0 711	0 223	1.374	2 861
June	0.398	1.706	0.671	0.115	1.181	2.890
July, Aug.	Filters out of service					
Sept.	0.494	2.171	0.987	0.054	1.535	3.706
Oct.	0.436	2.000	0.907	0.058	1.401	3.401
Nov.	0.543	1.855	0.766	0.166	1.475	3.330
Dec.	0.498	1.495	0.568	0.217	1.283	2.778
1913						
Jan.	0.347	1.658	0.836	0.077	1.260	2.918
Feb.	0.300	1.538	0.774	0.061	1.135	2.673
Average for these 12 mos.	0.43	1.77	0.68	0.14	1.25	3.02
Average for Sept., Oct. and and Nov.	0.49	2.01	0.89	0.09	1.47	3.48

The above table gives the cost of operation per million Imperial gallons for somewhat more than a year. The cost of filter cleaning during the first few months was low, owing to the fact that the filters at that time were so new as to require but little cleaning. No costs are given for the months of July and August, 1912, as the plant was out of service nearly the whole of those two months. The method of operation followed during the winter period involves the storage of several thousand cubic yards of filter sand in the filters over the winter, which has to be washed and restored in the following summer. At the end of the period covered by this table the plant was in that condition and the cost of sand handled during the few subsequent months will, therefore, be considerably increased. The average given for the twelve months is, therefore, lower than the normal annual average cost of operation, which is likely to be

more like the figures given for September, October and November, 1912, or even somewhat higher.

The plant was built under the direction of Mr. C. H. Rust, City Engineer of Toronto, with the writer in local charge. Messrs. Hazen and Whipple prepared the plans and acted as consulting engineers throughout the work. The operation of the plant is now in the hands of the Works Commissioner of Toronto, R. C. Harris, Esq.

MOBILE WATER SUPPLY

By Edgar B. Kay

HISTORICAL STATEMENT

The legislature of the state of Alabama in the year 1820 authorized the formation of a corporation to be known as "The Mobile Aqueduct Company." Messrs. Lewis Judson, Addison Lewis, Archibald N. Gordon, Wm. H. Robertson and Francis W. Armstrong, their heirs, etc., were named as incorporators.

This act approved December 20, 1820, states that, "Whereas, it has been represented, that it would be of singular advantage to the health and convenience of the city of Mobile, to be supplied with water from some running stream in its vicinity . . . and whereas it has also been represented that certain individuals have agreed to associate themselves together for the purpose of conducting a supply of water from a creek called the Three Mile Creek, otherwise Bayou Chatogue—and provided that said corporation should construct an aqueduct of logs 'with a calibre large enough to contain and conduct a sufficiency of water to supply the citizens and other persons of Mobile with water' and that the corporation should 'have and enjoy the exclusive right and privilege of conducting and bringing water for the supply of said city, for a period of forty years,'" at the expiration of which time the works were to become the property of the city. Under the terms of this act water was to be supplied to the city within three years.

The above corporation failed to construct the works provided for in the legislative act, and on December 24, 1824, the legislature of the state of Alabama transferred to, and vested in, the corporation of the city of Mobile, for the use and benefit of the inhabitants thereof "all the rights, privileges and immunities, powers, prerogatives and authority," which appertained to the above Aqueduct Company.

Nothing was done by the city for six years. In 1830 a committee was appointed by the Mayor and Aldermen of the city to procure information on the subject of bringing water into the city, and on

November 10 of the same year a report was submitted giving the following data with reference to a spring which was recommended as a source of supply: "A spring situated about ¾ of a mile north of the Three Mile Creek, a tributary of said creek and near the residence of Judge Lipscomb, at Spring Hill." The committee states that said spring "is about six and one half miles distant from the east side of Commerce Street, and has an elevation of thirty six feet seven and one half inch above the surface of the ground at the intersection of Dauphin and St. Joseph Streets."

December 12, 1830, articles of agreement were made and concluded "by and between the Mayor and Aldermen of the city of Mobile and John L. Martin, William McCullan, John S. Glidden and Thomas Torrey, that they shall, on or before the first day of January, 1832, construct and finish an aqueduct, for the introduction of water into the city of Mobile from a spring, near the late country residence of Judge Lipscomb at Spring Hill, to the city of Mobile."

The pipes or conduits were to be made of yellow pine of good quality and laid to the city in the most direct route so as to cross the Three Mile Creek just below Page's old place at Spring Hill, and at or near the place where Eslava commenced a canal; thence in a straight direction, as the ground would permit, to the Spring Hill Road, thence along said road to Dauphin Street; the calibre of each pipe or conduit to be five and one half inches in diameter from the spring to Pollard's Hill, and thence to town or intersection of Dearborn and Dauphin Streets, four and one half inches.

Up to December, 1836, wooden and cast iron distribution pipes had been laid by the corporation of the city of Mobile in the middle or center line of the following fourteen streets:

Wooden Distribution Pipes

Dauphin	St.	Dearborn	St.	to	the River.
Claiborn	"	Dauphin	"	"	Government Street.
Government	"	Claiborn	"	"	River.
Conception	"	Government	"	"	St. Michael Street.
St. Michael	"	Conception	"	"	River.
Water	"	St. Michael	"	"	Church Street.

Cast Iron Pipe of Three Inch Bore

Dearborn	St.	Dauphin	St.	to	Conti Street.
Lawrence	"	Dauphin	"	"	St. Louis Street.
Joachim	"	Dauphin	"	"	St. Louis Street.
Conception	"	Government	"	"	Church Street.
St. Samuel	"	Government	"	"	Eslava Street.
Water	"	Church	"	"	Eslava Street.
Conti	"	Dearborn	"	"	Royal Street.
St. Francis	"	Franklin	"	"	Joachim Street.
St. Louis	"	Hamilton	"	"	St. Joseph Street.
Eslava	"	St. Emanuel	"	"	Water Street.

The above mentioned aqueduct and the distribution pipes laid in the middle of fourteen different streets of the city, formed or constituted the "Mobile City Water Works."

"December, 1836, the Mayor and Aldermen of the city of Mobile leased to Henry Hitchcock the above mentioned Mobile City Water Works, for the term of twenty years."

"December, 1837, the legislature of the State of Alabama incorporated the Mobile Aqueduct Company. No company was formed, and in 1838, Henry Hitchcock surrendered up the said Water Works, and all appurtenances thereto belonging, unto the Mayor and Aldermen of the city of Mobile."

On January 17, 1838, Mr. Hitchcock addressed a letter to the Mayor and Aldermen of the city of Mobile, in which he offered to transfer his contract with the city to the newly organized company provided the corporation assume his notes for $26,000, held by the city, and buy certain property for the privilege of the charter. This proposition was accepted, as noted above, and Mr. Hitchcock called into consultation an engineer, Mr. Albert Stein, of New Orleans, who submitted the following report:

NEW ORLEANS, January 29th, 1838.

HON. H. HITCHCOCK:

Sir:—You have again complimented me, by asking my opinion concerning "the best mode of introducing water from the Three Mile Creek into the city of Mobile, the plan of the reservoir, steam engine and pumps, the length and bore of the main pipe, etc., with the cost of the works, and their probable income."

I examined the creek last year and found it to contain an abundant supply of excellent water, fully adequate to furnish a population of 50,000 or 60,000 persons with wholesome water for all domestic purposes,

and at the same time to furnish an ample supply for public objects, in cleaning the streets and extinguishing fires.

The mode of introducing this water must be by constructing a reservoir about 1000 yards from the margin of the creek, where there is an eligible site; the reservoir to be filled by forcing pumps, and the water so obtained to be conveyed to the city, as far as Dauphin Street, by a main pipe, 2700 yards in length.

It would be invidious and useless for me to give a plan for this reservoir, steam engine and pumps, not to be constructed by myself. This must be left to the engineer actually engaged; and their dimensions based on the quantity of water necessary for all public and private purposes.

In considering the cost and income of the works, it will be necessary to recollect that 10,000 feet of cast iron pipes have already been laid, which can be rendered available; and that there are 6000 feet of 6 inch pipes on hand, thus considerably diminishing the outlay and it will be equally essential to remember that, while the cost of materials and labor are gradually becoming diminished, in the course of time, the demand for water will be commensurate with the increased population of Mobile; so that the cost of construction and maintaining the works must be gradually lessened while the revenue arising from their use will be as certainly augmented. The estimate of cost must be based on a knowledge of these facts.

I send you a plan of your city, that you may perceive the necessary distribution of pipes through the streets, and also a profile of the line of pipes from the creek, where the engine and pump house shall be erected, to the site of the reservoir, thence to Dauphin, and along Dauphin to the river. From the creek to the reservoir, 1000 yards of pipes of 10 inch bore will be required, and the main pipe from the reservoir into the city should be of 12 inch bore. The pipes required in Dauphin Street, 1350 yards, should be 10 inch and 8 inch, being for about 2400 yards. Fire plugs are to be erected along the line of the pipes for the purpose of extinguishing fires and washing streets, and stop-cocks placed to shut off water from pipes for repairs, making attachments, or cleaning them. The mean height to which the water has to be raised from the creek into the reservoir is 40 feet. The site for the reservoir is 20 feet higher than the highest ground in the city. I have made a minute enumeration of all required to raise and distribute 600,000 gallons per day, and an estimate accordingly, including reservoir, engine and pumps, and pump house. But it is not necessary for me to give you the particulars in detail. You may, however, rest assured that I have endeavored to be accurate in every particular, and you can be satisfied of the result thus briefly given of the probable cost.

Distribution pipes agreeably to plan	$65,171.50
Reservoir	25,000.00
Engine and pump house	10,000.00
Engine and pumps	12,000.00
Incidental expenses, etc	7,828.50
	$120,000.00

The whole outlay, exclusive of the land for the house and reservoir, would therefore be $120,000. The distribution (as set down) embraces a line of pipes from the pumps to the reservoir, thence to Dearborn in Dauphin Street, thence along Dauphine to the river. In Dearborn from Church Street to Adams, and in Joachim Street the same distance, amounting in all upwards of 4.25 miles of pipes including those necessary for fire plugs.

In ascertaining the probable income, we must calculate the annual cost of supplying the water, the quantity of water likely to be required and consumed by the people of Mobile. As the creek water is of a very superior quality, and as all families capable of having it conveyed to their premises are almost certain to be customers, we may believe that at least 2000 families will daily require its supply. Counting six persons in each family, and allowing each 30 gallons per day for every purpose, the quantity required per diem for consumption and supply will be 360,000 gallons.

To raise such a quantity into the reservoir and distribute it through the streets and hydrants, would not cost more annually than $5000. And if a larger quantity be hereafter necessary, the annual cost will be very little increased, so that while an increased consumption of the water by families will certainly increase the profits of the works, the increased supply will augment their cost of maintenance. This difference must be greatly to the advantage of the corporation, and will be more sensibly felt in three or four years. At present, however, the probable income will be ascertained on the above data.

2,000 families at $20	$40,000.00
Annual cost	5,000.00
Receipts	$35,000.00
Interest on capital, $200,000 at 6%	12,000.00
Net income	$23,000.00

You will perceive that had I assumed that 2500 families would require water, as in a very few years will be the case, or had I assumed twenty-five or thirty dollars as the annual average charge for each family, the clear income would be much greater.

In conclusion, I am clearly of the opinion that the works can be easily constructed; that the creek can afford an abundant supply of limpid and and soft water; that the Mobilians will generally use it, and that the works will shortly bring you a handsome income.

I have the honor to be your most obedient,

ALBERT STEIN.

The public did not respond to Mr. Hitchcock's proposition, and no company was formed. Mr. Hitchcock deeded to the city his interests in the water works and the same was taken up by Mr. Stein on his own responsibility. He signed a contract with the city for a twenty year term, December 26, 1840. This contract provided that Mr. Stein deliver water to the city within two years, also that

at the expiration of the twenty years, the value of the works constructed should be determined by six arbitrators, and the amount agreed upon be paid Albert Stein by the city or any time thereafter, when the works would become the property of the city of Mobile. All pipe on hand and all pipe laid were to be purchased by him from the city at the price they could be delivered at Mobile at the time of the purchase.

January 7, 1841, the agreement between Mayor, Aldermen and Common Council and Albert Stein was confirmed by the legislature of the State of Alabama.

The charter for the transportation of a supply of water from the Three Mile Creek for the use of the citizens and other persons residing in the city of Mobile is a contract between the state and the corporation of the city, which cannot be transferred, for a term of years, to a third party, without the consent of both parties. For this reason it was stipulated in the contract, that the mayor, aldermen and common council of the city of Mobile, "shall, as soon as possible obtain from the legislature of the State of Alabama, an act sanctioning the agreement, and the stipulation thereof, as contained." And that Albert Stein "will commence the aforesaid works within one month after obtaining the consent of the legislature of the State of Alabama, to the stipulations, agreements and transfers, herein made and contained."

It seems, however, that the plan outlined above in the letter of Mr. Stein to Mr. Hitchcock, was modified considerably and the point of intake on Three Mile Creek moved upstream several miles to the site later purchased by the city, and used as an auxiliary station. At this place it appears from all the writer can gather that both an under-shot wheel and a steam pump were installed and operated until purchased by the city in 1898; the engine operated by steam was probably an auxiliary unit for use in dry weather, but later used continuously, when the water wheel was abandoned.

In 1880 the population of Mobile had increased to more than 30,000 and there was an opportunity for another water company to do business. The Bienville Water Supply Company was incorporated April 9, 1886. Land was purchased by Samuel R. Bullock & Co., of New York, in the same year, and the Bienville Water Supply Company's plant erected, on Clear Creek. Water was delivered through the mains of the new system to the citizens in 1887. The following year the Bullock property was transferred to the Bienville Water Supply Co.

The Bienville and Stein plants were operated independently until 1898 when the city of Mobile decided to take over the Stein works. At this time the majority stock of the Stein corporation was held by Philadelphia people, who declined to abide by the decision of the arbitrators appointed to determine the value of the Stein (Mobile Water Works) property, the ascertained value of the property or price to be paid by the city of Mobile having been fixed at $55,000. After some litigation the city succeeded in acquiring possession of the Stein property.

On account of the increasing demands for additional water supply and a delivery at higher pressure, the city of Mobile decided to erect a new pumping station, build a larger storage reservoir and a new 30 inch supply line. During the year 1900, the present Spring Hill pumping station, reservoir and 30 inch force main were put into service, with Mr. M. F. Sullivan as superintendent. From the annual reports of that official, it is evident that the operation of the new Spring Hill equipment was unsatisfactory from the start. The furnaces had to be rebuilt, the speed control of pumps required constant attention, and the water in the lake was so shallow that it became polluted with vegetable organisms. It was proposed to clean out this impounding reservoir and increase the depth of the water in it, but the unprecedented rainfall of June 26, 1900, twelve and one-half inches in twenty four hours, caused the dam to be washed out and a sluiceway was constructed in its place. This sluiceway consisted of a canal 21 feet wide, of rectangular form, the sides being made of 2 inch vertical sheet piling. The piling on the east and north sides of this sluiceway have been removed.

Mr. C. W. Soost succeeded Mr. Sullivan as superintendent in 1903, and made his first annual report in the spring of 1904.

On July 1, 1901, the operation of the old Stein plant was discontinued, and the machinery disposed of in 1902. Most of the cast iron distribution system was taken up, and relaid, or sold.

In 1904 so many connections to the new works had been made that the supply in the Three Mile Creek at the Spring Hill station was insufficient to furnish the required water. An auxiliary pumping plant of 3,500,000 gallons daily capacity was installed on the site of the old Stein plant. The equipment consists of one B. &. W. boiler of 42–4 inch tubes 18 feet long with 42 inch drum 5 feet 10.5 inches long, a Webster Star vacuum heater and one Worthington pump No. 2039 with high, low and intermediate steam cylinders, with 14 inch suction and 12 inch discharge connections. This auxiliary plant was put into operation on October 2, 1905.

On January 8, 1907, the Bienville Water Supply Company deeded its entire holdings to the city of Mobile in the consideration of $350,000 city bonds, which were authorized by an election held August 6, 1906.

On July 1, 1908, the small auxiliary plant on the old Stein site was put out of service and has not been operated since that time.

The Spring Hill and Bienville plants have both been operated continuously since the city acquired the latter plant.

On October 1, 1911, the aldermanic form of government of the city of Mobile was changed to Commission form, and Honorable Harry Pillans, City Commissioner, became vested with the control of the water works department of the city.

It is interesting to note that in 1836 the amount of water estimated to be supplied to the citizens was 30 gallons per capita for all purposes, as compared with 214 gallons per capita in 1912, excluding the water used by the large manufacturing, railway, light and power concerns, and water used by vessels.

POPULATION

Mobile was incorporated as a city December 19, 1819. The growth of the city is shown in the following table:

1820	2672
1830	3194
1840	12672
1850	20575
1860	29258
1870	32034
1880	29132
1890	31076
1900	38469
1910	51529
1912	54179

In the year 1870 the area of Mobile was reduced, and the name changed to the Port of Mobile, which explains the falling off of population as indicated in the census of 1880.

From the above table it will be seen that the city of Mobile had a population of about 3200 inhabitants in 1830 when the Mobile City Water Works was contracted for. The population had increased to 12,672 in 1840 when Mr. Stein entered into a twenty

year contract. In 1900 or three years after the construction and operation of the Bienville Water Supply Company's plant the population had reached 38,469. In the twelve years that have since elapsed, the population has increased 41 per cent, and the new conditions again demand immediate attention.

1912 DAILY CONSUMPTION

Average daily consumption for all purposes,	12,433,301	U. S.	gallons.
" " " large users,	1,313,000	"	"
" " " domestic purposes,	11,120,301		
" per capita " for all purposes	230	gallons	daily.
" " " " for domestic and public use including waste,	205	"	"

Approximately 10 per cent of the Mobile water consumption is used by the railroads, shipping interests and manufactories, while 90 per cent or 205 gallons per capita daily, represents the water consumption for domestic and public use and the water waste. The following table gives the average daily consumption of water at Mobile, total number of taps and consumption per tap as shown by the reports of the Water Works Superintendents published in the annual reports of the city of Mobile:

YEAR	TOTAL CONSUMPTION, GALLONS	AVERAGE DAILY CONSUMPTION, GALLONS	TOTAL NUMBER OF TAPS ACTIVE	CONSUMPTION PER TAP
1903	3,148,820,275	8,546,300	6,219	1,400
1904	2,613,483,644	7,162,967	6,935	1,135
1905	2,360,849,290	6,468,081	6,518	992
1906	2,687,036,718	7,635,718	6,864	1,112
1907	3,565,673,829	9,767,123	9,380	1,041
1908	5,701,692,129	15,678,400	9,901	1,583
1909	4,566,143,139	12,509,981	10,422	1,200
1910	4,751,893,065	13,018,886	10,755	1,210
1911	4,792,682,357	13,120,000	11,500	1,141
1912	4,538,154,988	12,433,301	11,651	1,067

The average daily consumption of water was 126 gallons per capita in the first year of operation of the Spring Hill Pumping Station. The consumption reached a maximum of 253 gallons in 1910, gradually decreasing, being 248 gallons in 1911, and 230 gallons in 1912.

The enormous pumpage during the year 1908 does not appear to have any justification, and the writer seriously doubts the correctness of the records. For the first half of the year, 1908, all these plants were in operation, the Stein plant being credited with approximately 100,000,000 gallons per month. In the month of July, when the demand should have been a maximum, the Stein plant furnished 2,000,000 gallons and was put out of commission, and the other two plants furnished about the same amount of water for the last half of the year as for the first half. It may be that there was an unusual demand for water during the first half of the year in question, but no evidence has been found by the writer to prove it. The writer believes that the reported amounts from the pumping stations were incorrect. It is seen that with a somewhat decreased rate of consumption, doubtless due to the increased percentage of taps metered, Mobile is consuming approximately three times as much water as is actually needed.

With no means of measuring the water consumption at present other than the revolution counters on the pumps at the pumping stations, there is no way except by an underground survey of obtaining accurate information regarding the flow of water in the various parts of the distribution system.

THE MINNEAPOLIS FILTER PLANT WITH A BRIEF HISTORY OF THE EVENTS WHICH LED UPTO ITS CONSTRUCTION

By W. N. Jones.

Minneapolis, like a great many other American cities of rapid growth, has suffered from time to time on account of not having had until recently a water supply which was reasonably free from all pathogenic bacteria. Relying as the city has, since 1868, upon the Mississippi River for its supply, it was only natural that there were times when epidemics of typhoid broke out which were traceable to the water as a source.

During the earlier days the river was the scene of extensive logging operations, and it is probable that at first most of the pollution of the river water was caused by this alone. Later, however, the city began to grow very rapidly and to spread out, with the result that, before very long, there were a considerable number of people in the city living above the water works intake who added materially to the pollution of the stream. From time to time, as new pumping stations were built, the intake was moved farther up stream, but the population rapidly followed. Then, too, the Mississippi River watershed, above Minneapolis, received its quota of people as well as the city, all of whom used the river more or less for disposing of their sewage. Before long, the natural result was that the river which had at one time been a fairly good supply was rendered dangerous for domestic purposes. From the first every indication pointed to an increased pollution of the stream as the years went by, which made it imperative that the city of Minneapolis should seek some other source of supply and abandon the river or the river water should be purified in some manner which would render it fit for all purposes.

A few of the farsighted citizens realized the above facts at a very early day, but nothing definite was done, nor are there any records of an agitation for a pure water supply until early in 1894. At that time the present city engineer, Mr. F. W. Cappelen, was

appointed city engineer and immediately began an active campaign for an improved and pure water supply.

At the fourteenth annual meeting of this society, held August 21, 1894 in Minneapolis at the West Hotel, Mr. Cappelen presented a paper entitled "Proposed Filtration and Purification of the Mississippi River Water and a New Plan of Distribution for the City of Minneapolis," the first part only of which will be to touch upon. After presenting a mass of data and authority for the same, Mr. Cappelen says: "It is plain that aside from the exceedingly troublesome spring water, the Mississpipi River is more or less polluted below Anoka. This pollution is going to increase, and, it is my opinion, that the river water, as now taken, is not the proper drinking water, but should be purified, and the best method of such purification is a mechanical filter with the proper coagulant, built on the gravity plan." Still farther on Mr. Cappelen says, "With the tremendous consumption at present, but only for a short time, a plant of 38,000,000 gallons would be required. I think, however, that by more closly regulating the waste, this figure could be cut to, say 30,000,000, and the necessary increase in number of filter beds could be added as required. With the 30,000,000 gallon filter plant, we would have very nearly double the capacity of the average daily consumption, and by constructing a storage reservoir of 93,000,000 gallons, a surplus could always be had on hand to provide against the very heaviest draft at the mentioned rate of 30,000,000 gallons. The location of these works will necessarily be on the site I located last winter, on lands in Anoka outside the city limits. The water will leave the filters through a 42 inch main running along the north side of the reservoir. The reservoir could be commenced with its pipe lines, or the main lines could be built first, and in the mean time, while this work is going on, the pumps could be ordered and be constructed and at last then, the filter plant would be put in. It has for some time been considered to cut the present rate of 8 cents per 1000 gallons, which is very low; I would suggest to leave the present rate and give first-class water and I am sure that nobody will object to the water rents."

The writer has cited the above quotations from the 1894 Report in order that you may all see and understand how near the plan as proposed by Mr. Cappelen 16 years before was carried out in the present system of filtration and wishes you would keep the same in mind when he comes to explain the plant and its design later on. Too much credit cannot be given Mr. Cappelen for his far-sighted-

ness in this matter. After Mr. Cappelen's report two settling reservoirs each of a capacity of 47,000,000 gallons were constructed on the site selected by him and above referred to, but nothing further was done in the matter of giving Minneapolis a better water supply until early in the year of 1904 when a typhoid fever epidemic broke out, which was traced directly to the use of city water. This resulted in the permanent closing down of two old pumping stations which were located in the heart of the city just above St. Anthony Falls and the appointment of a commission by the City Council, consisting of Messrs. Andrew Rinker, city engineer; F. W. Cappelen and Allen Hazen, "to investigate and report the best method of filtration of water from the Mississippi River, and the cost of the necessary filtration plant." After an investigation covering several months, during which time the commission visited and studied a large number of water purification plants throughout the country, they reported in favor of slow sand filters located on the site adjoining the reservoir, and recommended that 16 filter beds be provided with an effective area of $13\frac{1}{3}$ acres, that a new covered clear water basin of 20,000,000 gallons capacity be constructed, together with all the necessary piping and appurtenances, and a new 60 inch steel force main be laid to Central Avenue and connected to the existing piping at that point in order to fully maintain the required pipe capacity. The total cost of the improvement as outlined was estimated to be $1,276,000.

The commission, believing that every available source of water supply should be investigated, included in their report Lake Superior, Lake Mille Lacs, and artesian wells, all of which were dismissed as impractical for one reason or another.

The Lake Superior project would require a pipe line 160 miles in length; the reservoirs are situated on ground at an elevation of over 400 feet above the lake, with intervening ground at least 150 feet higher, over which the water would have to be pumped; the estimated cost of this project was $15,000,000 for pipe line and pumping stations and the operating expense for 27,000,000 gallons, daily capacity was estimated to be about $200,000 annually. Then, too, the lake water was very liable to become contaminated at any time and the risk of depending on a single pipe line was very great, all of which goes to show the impracticability of this project.

To have used the artesian well water successfully it would have been necessary to have installed a softening plant as the water was very hard, in general, two or three times as hard as the river water.

Low lift pumps would also be a necessary adjunct to the wells and it was very doubtful whether a sufficient quantity could have been obtained from this source within a reasonable distance. "The process of softening would have been substantially as expensive as the filtration of the Mississippi River water and the water secured no better than the treated river water." This source was, therefore, eliminated from further consideration.

The Mille Lacs project was very inviting. The lake which has a drainage area of 437 square miles, including the lake itself (190 square miles in extent), is a very beautiful sheet of water with only a few small islands and from 30 to 40 feet in depth, although in places it is very much deeper. It is situated about 80 miles a little west of north of Minneapolis in a wild and sparsely settled country and there were but few sources of pollution in 1904. The quality of the lake water as shown by examinations at this time was very much better than the river water. It was only half as hard as the Mississippi River water and was nearly free from turbidity and color. Being 225 feet higher than the reservoirs, it offered a gravity flow to the city and would have eliminated all pumping. The estimated cost of the necessary works, including 80 miles of 66 inch steel pipe which would bring 40,000,000 gallons of water to the city every day was $6,340,000.

The City Council adopted the commission's report, September 9, 1904, with the recommendations as above stated and at a general election in the fall of 1904 put the question of issuing bonds for the project to a vote of the people who voted it down, not realizing, evidently, the value of a pure water supply to the city. The people, having expressed themselves on this matter, it was allowed to rest until early in the spring of 1909 when a commission known as the "Pure Water Commission" again took up the matter. This commission was appointed at the instance of the City Council and consisted of 21 representatives from as many civic organizations of the city.

This commission, feeling that the question of a pure and adequate water supply for the city of Minneapolis was a very important and vital one, decided not only to investigate the different methods of purifying the Mississippi River water, but also any and every source of water supply which seemed to possess any merit of being pure and adequate.

They received and reviewed a large mass of testimony from experts in water supplies, engineers, chemists, geologists and bacteriolo-

gists, relative to the best method of securing a pure water supply. A great many filter plants of both types throughout the country were visited and investigated. Letters were written to foreign countries relative to their water supplies and answers received. The artesian wells, Mille Lacs Lake and the Mississippi River supplies were again investigated relative to their various merits and on June 16, 1909, the commission brought in a majority and a minority report.

The majority reported in favor of purifying the Mississippi River water and that, in order to satisfy the public, it should involve the removal of the turbidity, color, taste and smell as well as the harmful bacteria. They recommended that the City Council appoint a commission to be known as "The Minneapolis Water Commission" consisting of 5 citizens to serve without pay and the Water Committee of the City Council, that an expert engineer be employed to serve as advisor to the commission and the appointment of such other assistants and workmen as were necessary to carry on the work. They also recommended the construction of an experimental water purification plant at a cost not to exceed $25,000 for construction and equipment, wherein the Mississippi River water could be "treated and tested daily by the various methods of purification for a full year so as to cover and include all seasonal variations. Such tests as were carried on and the conclusions reached by the commission were to form the basis for the type of purification works to be built."

The minority reported in favor of securing the supply from Mille Lacs Lake, basing their report on: (1) because none of the experts consulted would say that either system of filtration would give a water entirely pure or free from harmful bacillus; (2) each one of the experts admitted that the greatest care should be taken in the management and the operation should be in charge of scientific men; (3) there was strong evidence that not all filtration plants had been unqualified successes; (4) the hardness of the Mississippi River water at Minneapolis; (5) after hearing such evidence as was presented on the purification of the river water, the committee said, "We would not drink Mississippi River water put through any kind of a filtration plant that could be built"; (6) the expenses of the operation of the filter plant, softening plant and pumping stations were so great that, taken together with the first cost, would work a hardship on the taxpayer. After the above reasons for not wishing any kind of a filter plant installed, the minority report

says, "We find the water is absolutely pure (meaning Mille Lacs Lake) and the very best kind for the human system as shown by testimony, that it is as clear as the water of a mountain spring, and, with the exception of the waters of Lake Tahoe in Nevada, it is the clearest water to be found in any lake in the United States."

The minority report further recommended that the city employ several expert engineers of the highest possible reputation to make such exhaustive investigations as would forever satisfy the people of Minneapolis that everything possible had been done to make certain that the best source of supply had been determined upon and that no mistake had been made in the final decisions.

The report of the commission not being fully in favor of any definite project, the City Council felt that it would be well to move with caution on so vital a question as a pure water supply for the city. They, therefore, decided to investigate more fully the two sources recommended by the pure water commission. With this end in view, Mr. Rudolph Hering of the late firm of Hering & Fuller of New York City was called in and on October 13, 1909, he was retained with full authority to act in this matter in any way that he saw fit. He was instructed to make such investigations as to quantity and quality as were necessary and to render a report as soon as possible.

From November 3, 1909, to March 17, 1910, Mr. Hering made a very thorough examination of the existing water works relative to using the same in connection with a filter plant. A party was taken to Mille Lacs for the purpose of examining the water shed as to topographical and geological features, the character of the water, the depth of the lake and the amount of its discharge. A re-survey of the proposed pipe line was made and everything possible done to make sure of the better and cheaper supply.

It was found that the surface of the lake was 227 feet above the city reservoirs and would give a gravity flow, but that the pipe line would have to be 80 miles in length. The lake water was found to be very similar to that of the Mississippi River water except that the contamination and hardness were less. The average flow was found to be much less than was anticipated, it was not certain that the city could be assured of more than a 40,000,000 gallon supply at all times. From Mr. Hering's examinations and survey, he concluded that it would be necessary to build a filter plant, even if Mille Lacs were used as a supply, as the quality of the water in its raw state was not such as to be fully acceptable as a municipal

water supply. As an additional safeguard, a hypochlorite plant was also decided to be necessary. The estimate of the cost of the necessary pipe line, headworks and filter plant of the mechanical type to handle 40,000,000 gallons per day and the hypochlorite plant to treat 30,000,000 gallons per day, the amount then deemed sufficient, was $6,832,149 with an annual cost for upkeep and operation of $432,126.

Mr. Hering also found the river water polluted by sewage at the river intake of the pumping stations. The turbidity was found to be slight, the color at times quite high, the hardness much greater than the lake, but the "microscopic fauna and flora less." During the hot weather, at certain times, a slight odor was noticeable.

COMPARATIVE ANALYSES

	Mississippi River	Mille Lacs Lake
Chlorine	1.490	.86
Albuminoid ammonia	.353	.416
Free ammonia	.077	.085
Alkalinity	137.000	78.820
Total hardness	145.000	103.250
Fixed residue	129.000	54.210
Volatile residue	69.000	60.80
Color	56.630	9.00
Turbidity	4.700	9.43
Bacteria	1622.000	177.00

This table shows the comparison between the two waters. The table for the Mississippi River water is an average of several years of analysis, while the table for the lake water is an average of 21 samples taken during August, October and November of 1909. All analyses were carried on under the direction of Dr. J. F. Corbett, city bacteriologist.

On March 17, 1910, Mr. Hering submitted his report in favor of continuing the use of the Mississippi River as a source of supply and recommended that it be purified by a mechanical filter plant and disinfected by means of hypochlorite of sodium or calcium without softening. The estimated cost of a 30,000,000 gallon plant was $522,500.

The report of Mr. Hering was immediately adopted by the City Council and the former firm of Hering & Fuller of New York City

were retained to draw up such plans and specifications as were necessary for the above plant. During the summer of 1910, however, a very dry spell occurred and the consumption of water increased until the capacity of the filter plant, as ordered, was almost reached. This warning was heeded by the City Council and instructions were given Messrs. Hering & Fuller to increase the capacity of the plant to 39,000,000 gallons per day with provision whereby other filters could be added as needed until the capacity was increased to 52,000,000 gallons per day. This was done and the estimate was advanced to $616,000 with $70,000 for engineering, etc.

During the winter of 1909–1910 while the different projects were under investigation, an unusually large number of typhoid fever cases occurred in the city which could be traced to the river water as a cause.

The accompanying table shows the death rate for the corresponding months of January and February of 1909 and 1910.

	1909	1910
January	1	11
February	1	31

The Minnesota State Board of Health in conjunction with the city health department recommended the immediate construction of a hypochlorite plant capable of treating 20,000,000 gallons of water per day. This plant was built and put in operation as soon as possible at the N. E. Pumping Station and continued to be the only method of purification of the river water until the new filter plant was put in service January 10, 1913.

The accompanying table shows very nicely the progressive effects of the hypo treatment.

The colon bacilli disappeared from the city hall tap after the second day of treatment although continually present in the raw river water.

Treatment Started February 25, 1910

DATE	RAW RIVER WATER	DISCHARGE 10 MIN. AFTER TREATMENT	RESERVOIR		CITY HALL TAP
			Inlet	Outlet	
Feb. 24....	Colon	..	Colon	Colon	Colon
25....	"	..	"	"	"
26....	"	0	0	"	"
27....	"	0	0	0	0
28....	"	0	0	0	0
Mar. 1....	"	0	0	0	0
2....	"	0	0	0	0

FILTER PLANT

The new filter plant is situated on the high ground adjacent to the old city reservoirs in the Village of Columbia Heights, Anoka county, Minnesota, about 1½ miles north of the northern limits of the city of Minneapolis. Here the city owns about 200 acres of land, a part only of which is occupied by the present works. It is the intention to park the unused portion at some future time, retaining a part only for future extensions.

The filter plant comprises a meter chamber, mixing chamber, two coagulation basins of approximately 1,400,000 gallons each, a

FRONT VIEW OF PLANT. SETTLING BASIN IN FOREGROUND.

head house, 12 mechanical filter units of 3,250,000 gallons per day capacity each, 2 auxiliary clear water basins of about 600,000 gallons each and a 135,000 gallon wash water tank, all surmounted by red brick buildings of appropriate design, covered with a red asbestos shingle roof. In addition the works include a 75,000,000 gallon settling basin, a 45,000,000 clear water basin covered with a groined arch vaulting of concrete, and two pumping stations of a combined capacity of 95,000,000 gallons per 24 hour day as well as such mains and laterals as are necessary to properly distribute the water throughout the city.

In designing the filter plant it was desired to economize as much as possible by making use of the old existing works wherever this could be done. Upon the recommendation of Mr. Andrew Rinker, who was then city engineer, it was decided to raise the embankment

of the old south reservoir 10 feet and cover the old north reservoir with a groined arch roof of concrete with an earth covering to act as a clear water basin. By doing this, it was possible to get a gravity flow through the filters and still maintain the same head on the city mains. All parts of the plant are grouped and connected in such a maner as to allow the maximum flexibility in operation. Wherever possible, piping was eliminated and replaced by reinforced concrete conduits or by direct connections between the various chambers or conduits.

A great deal of study was put on the handling and mixing of the chemicals and their introduction into the water. Special features were introduced to facilitate the application of the coagulant and

Coagulation Basin and Mixing Chamber Gate-House, Showing Slab over Top of Basin Discontinued.

hypochlorite solutions and, with a few minor changes, have worked very nicely.

Several times during the period in which the plant was under design, Mr. Andrew Rinker visited New York, consulted with the designers and offered many valuable suggestions which were subsequently carried out.

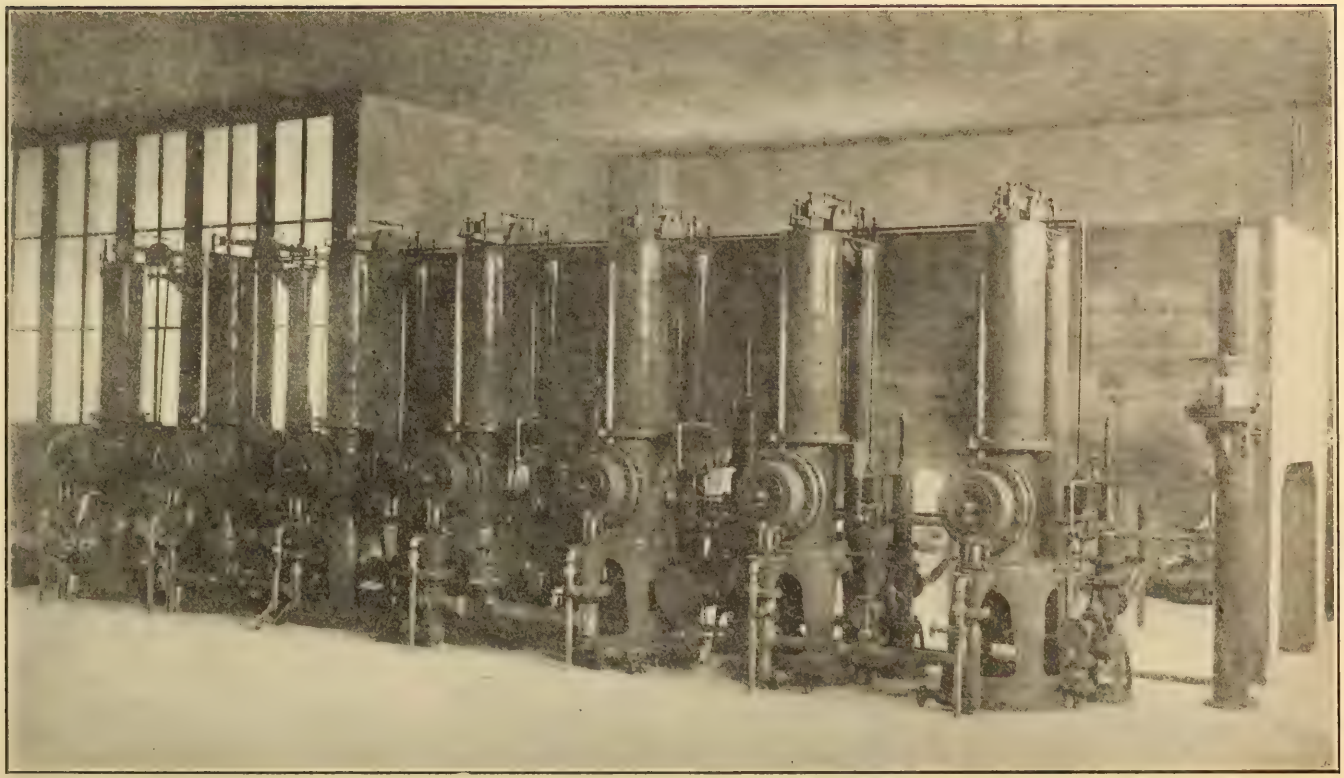
The controlling and mixing chambers may be treated as one structure, although there is an irregular dividing wall between them. Together they form a covered chamber, 8 feet 34 inches by 173 feet, inside measurements, having a flat slab of concrete for a roof of the beam and girder construction, supported by concrete walls and columns placed at suitable points and supporting a superimposed load of earth 24 inches thick over the greater part of the

area, and one side of the gate house over the remaining portion. As you will notice the slab covering or roof is discontinued inside the gate house leaving the waterways open to inspection. Although the original design did not contemplate it, an iron railing showing in the cut was placed around all openings in the gate house to prevent any children or visitors from falling overboard. You will also notice that the left or west side of the gate house is supported over the coagulation basins in the same manner as the right or east side is supported over the mixing chamber.

The controlling chamber contains a 60 inch by 30 inch venturi meter for measuring the total flow of water to the plant and for actuating the chemical feed controllers. This meter is of reinforced concrete, excepting its upstream end and throat which are of cast iron lined with bronze and it is placed low enough in the controlling chamber to be submerged at all times during the operation of the plant.

At 3 foot intervals across the mixing chamber are placed wooden baffles of around-the-end type which mix the chemicals and water very thoroughly as the water passes through. Provision is made, by means of gates placed at intervals, whereby the water can be drawn off as desired into the center passage and thence into either or both of the coagulation basins. It might be well to explain that the center passage is a double reinforced conduit, the lower portion of which carries the mixed water from the mixing chambers to the coagulation basins and the upper portion of which takes the water from the coagulation basins and delivers it to the 60 inch influent piping running to the filters. For cleaning out the chambers, sumps connected to the 12 inch drain and closed by 12 inch sluice gates are provided at intervals. Whenever a baffle wall interferes with the free flow of the drainage to these sumps, wooden gates have been placed which can be very easily opened from the floor above when occasion demands. All cleaning of the chambers and coagulation basins is done by flushing, either by means of a 500 gallon per minute centrifugal fire pump or by means of a 20 inch gravity pressure line from the controlling chamber.

The coagulation basins, two in number, are each 119 feet 4 inches by 95 feet 8 inches, inside measurements, and are similar in construction to the construction of the mixing and controlling chambers, being of the beam and girder type. They are separated from each other by means of a dividing wall but water from one can be passed into the other by means of a 60 inch by 48 inch sluice gate placed



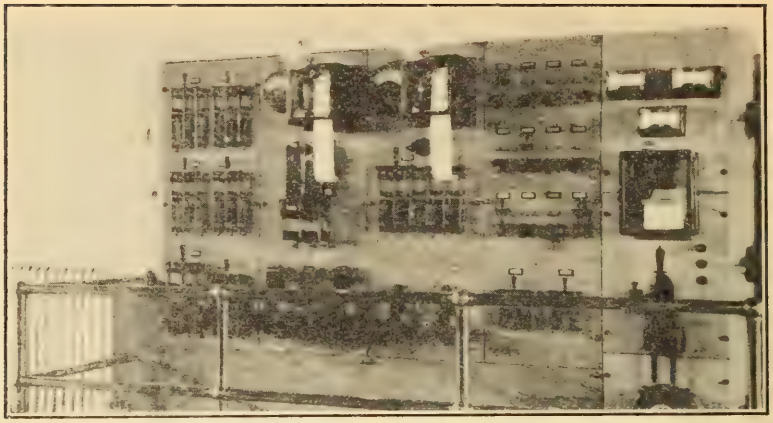
Chemical Feed Controllers in Foreground, Chemical Feed Tanks in Rear.

in the dividing wall for this purpose. At regular intervals across each basin are placed four reinforced concrete baffle walls of around-the-end type, giving the direction of flow and preventing any dead water therein. These walls, which are 4 inches thick, were cast monolithic with the roof, girders and columns and, to give stability at the bottom, a groove was left in the foundation concrete to receive the foot of each wall. Skimming weirs about 25 feet long are provided in each basin for skimming off the water near the surface. These weirs are of reinforced concrete excepting about 7 feet of the middle portion, which is made by sliding wooden stop planks one inch thick in grooves left in the concrete for this purpose. The stop planks are introduced as a means of safety as well as to provide a method of varying the height at which the water may be skimmed off. In case that any undue pressure was suddenly thrown on one or the other side of the weirs, these planks, being very thin, would immediately break, allowing the water to equalize the pressure on both sides, and perhaps prevent a more serious break elsewhere. For cleaning out the coagulation basins sumps connected to the 12 inch drain and closed by sluice gates are provided and the method of cleaning is the same as in the mixing chamber except that no gates are placed in the baffle walls, each section between baffles having a sump and sluice gate of its own with a floor sloping towards them which greatly facilitates the cleaning.

HEAD HOUSE

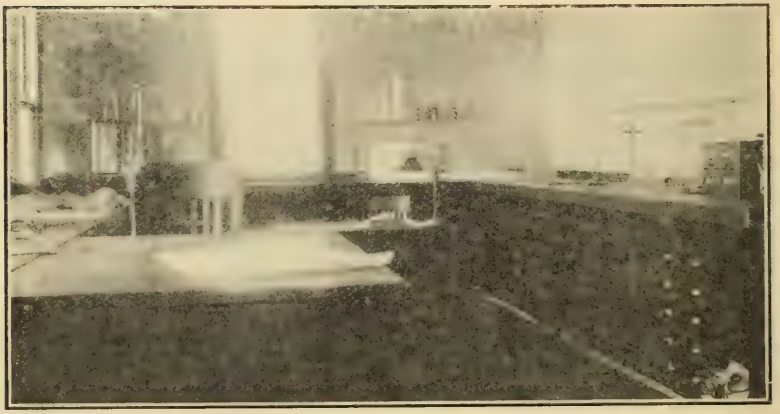
The head house or main building of the plant is a three story structure 115 feet long by 58 feet wide with an extension or entrance in front 51 feet 5 inches by 15 feet, and a tower at its center reaching about 54 feet above the main portion of the structure. On the lower or basement floor are situated the two wash water pumps, six chemical feed pumps for pumping the chemical solutions to the chemical feed tanks, two pressure pumps for furnishing the necessary pressure to all the hydraulic valves throughout the plant, a sump pump for keeping the basement free of water, a vacuum cleaning machine of one sweeper capacity, a rock crusher for crushing lime, the machinery for the freight elevator and two boilers for heating the entire plant.

The floor above is given over to the handling and mixing of the various chemicals used in the purification process. Here are located the dissolving and mixing tanks, with their various agitators, two concrete mixers for slaking the lime, a gas machine for



Main Switch Board in Head House.

Bacteriological Laboratory.



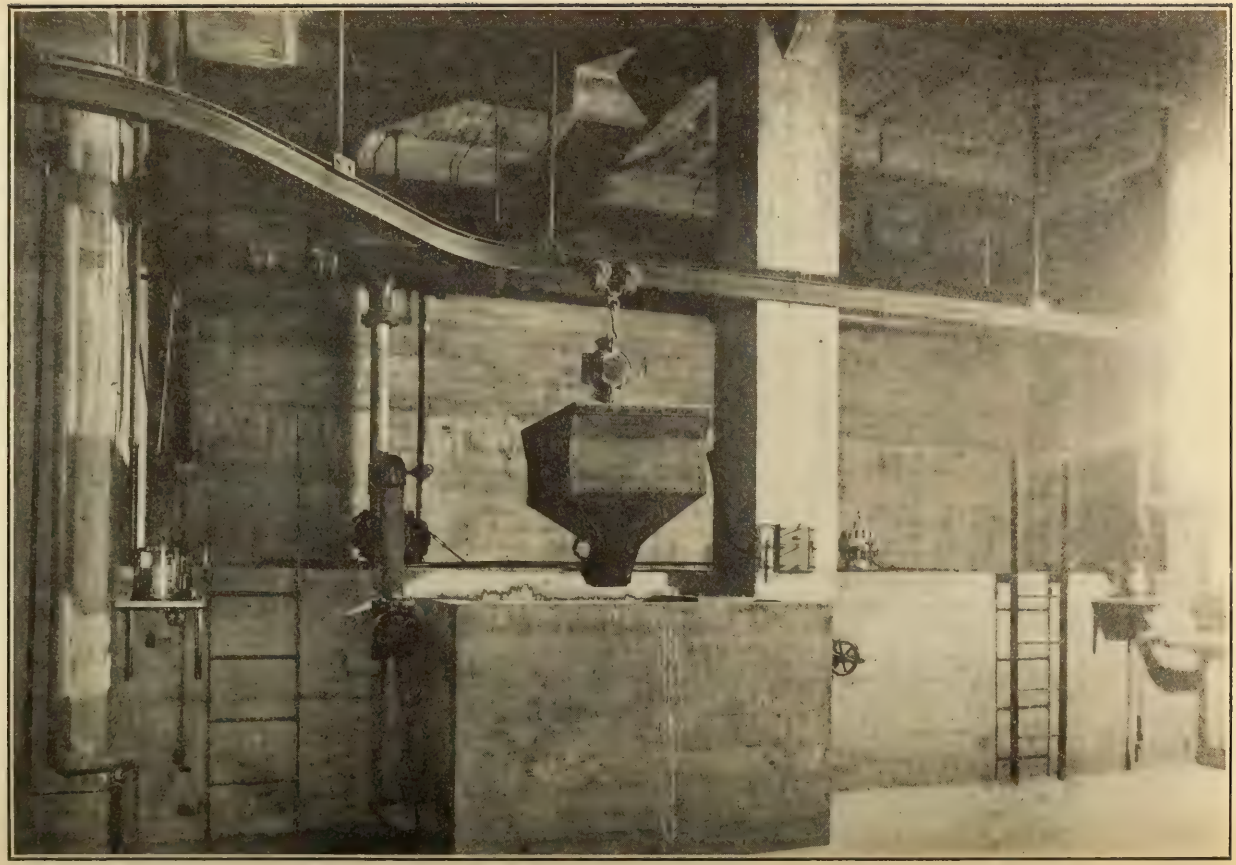
Chemical Laboratory.

generating the gas used in the laboratories, a fire pump of a capacity of 500 gallons per minute against 100 pounds pressure, an overhead trolley and weighing system for weighing and transporting the dry chemicals to the various plants, a venturi meter for measuring the water used in mixing the chemicals, and all the necessary chemical gages. The ground or third floor contains the office, laboratories, toilet rooms, transformer room, store room, main switch boards, chemical feed controllers, chemical feed tanks, venturi meter recording apparatus and all of the smaller apparatus for operating the plant.

Between the second and third floors just below the front entrance is located a receiving room. Here all of the chemicals except the hypochlorite are received from the wagons by means of iron chutes placed at either side of the front entrance and separated from it by brick partition walls. The main entrance to these chutes is closed by rolling steel doors. Just over the main entrance and occupying the same space is located the room for storing the drums of hypochlorite, and also a room for the storage of ashes. These rooms are closed by suitable doors which are kept closed, thus eliminating a great deal of the odor from the hypochlorite.

The tower before referred to contains the chemical storage bins and the upper end of a bucket elevator. The chemicals, as they are received in the receiving room, are shoveled down a chute into the bucket elevator, or into the lime crusher and then into the bucket elevator, as the case demands. The chemicals are then hoisted to the top of the tower by means of the elevator and spouted from there by a 10 inch spout with flexible couplings to any one of the twelve storage bins, each of which has a capacity of about two carloads of the dry chemicals. The handling and mixing of the chemicals is made as simple as possible, and wherever it has been possible to use machinery and gravity, this has been done. The cans of hypochlorite are opened on a grate in a small concrete tank below the surface of the water. The empty drum is then removed and the hypochlorite flushed into the middle receiving tank, where more water is mixed with it and the whole thoroughly agitated. The solution is then drawn off into either or both of two larger tanks placed alongside of the other, and sufficient water added to make the solution of the proper strength. Here it is again agitated from time to time as it is being used.

The alum, after being weighed, is brought by means of the trolley and iron buckets to a dissolving tank and dumped therein. This



Chemical Mixing Room, Showing Alum Dissolving and Mixing Tanks and Trolley System.

LIME MIXING APPARATUS.

tank contains an iron pipe grid and as soon as sufficient alum, which has been predetermined in the laboratory, has been dumped, a flow of water is turned through the grid and upward through the alum. The water dissolves the alum and carries it into the solution tanks, where the solution is agitated by means of an impeller and if desired diluted further.

For slaking and mixing the lime, two conrete mixers of 40 cubic feet capacity each are provided. As soon as the mass is sufficiently mixed, it is dumped into a trough whence it finds its way by gravity into any one of three large steel tanks, where it is agitated similar to the hypo and alum and made into lime water by the proper dilution.

The solutions are pumped up from the various solution tanks to six small concrete chemical feed tanks on the ground floor of the head house and fed by means of gravity to the proper chemical feed controllers from which the solutions run to the proper points of application.

FILTERS

The filters, twelve in number placed six on each side of an 18 foot pipe gallery, have each an effective sand area of 1173 square feet. They differ very little from the filters at Cincinnati and elsewhere. They are of reinforced concrete, rectangular in plan, 52 feet x 26 feet 8 inches, inside measurements, each divided into two parts by a central wash water gutter 3 feet wide to which are attached 16 lateral gutters at regular intervals along each side. At the normal rated capacity of 125,000,000 gallons per acre per day, each unit is capable of taking care of 3,250,000 gallons per day, but all piping is designed to carry a 50 per cent overload if this ever becomes necessary.

All washing is accomplished by means of an upward flow of water at a comparatively high rate, using, at times, as much as 15 gallons of wash water per square foot of area per minute. No air is used for agitating the sand, full dependence being placed upon the vertical rise of the wash water alone to carry off all of the deposits.

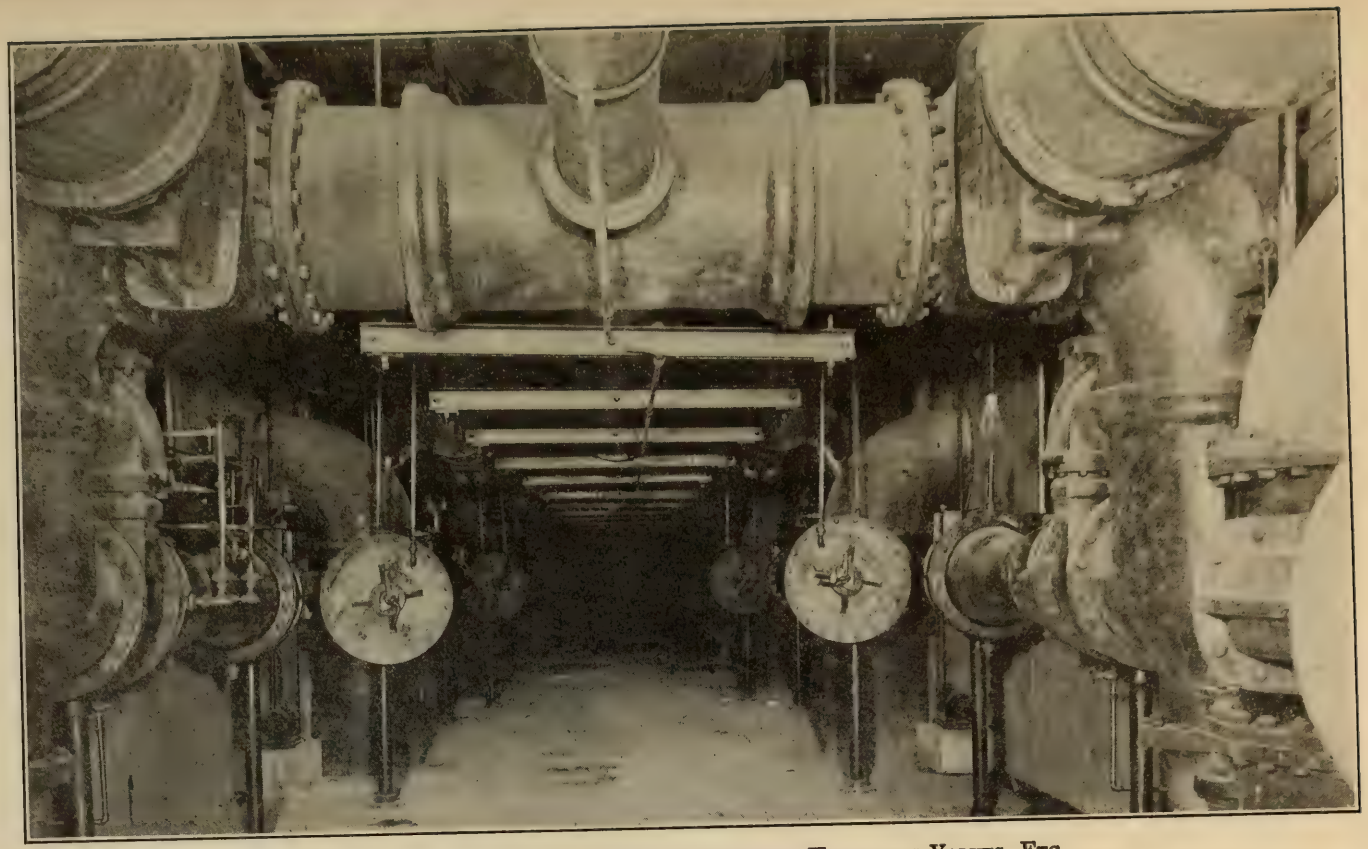
The sand in each filter is 30 inches deep and is sustained above the strainer plates by means of 4 courses of gravel ranging in size from $\frac{1}{12}$ inch at the top to 1 inch on the bottom next the plates, the total depth being 8 inches. This is maintained in its proper place during washing by means of a brass wire cloth, 10 meshes to the

Operating Gallery, Filter Building.

inch, of No. 20 B. & S. Gage Wire. The wire cloth is in turn held down by 2 inch brass washers over $\frac{1}{4}$ inch brass bolts imbedded in the concrete ridge blocks. The entire bottom of each filter box is made up of alternate ridges and grooves about 13 inches deep, spaced 12 inches on centers and extending crosswise of each filter unit. Each ridge in every half filter box is divided into three sections. The two outer sections are longer and rest directly on the filter bottom. The middle or shorter section is but 8 inches deep and rests at each end on an offset 5 inches high, cast monolithic with the outside sections. A space is thus left under each center section and as the strainer plates are placed at a height equal to the height of the center section above the bottom of the filters, a main waterway with a series of laterals is formed. These waterways are in turn connected by eight 14 inch bell-mouthed cast iron outlets to a manifold of 18 to 24 inch piping which serves as effluent piping for carrying the effluent to the controllers, and as wash water piping for conveying the clear water for washing the filters.

Below each battery of six filters on either side of the pipe gallery is an auxiliary clear water basin of about 600,000 gallons capacity into which the rate controllers discharge direct with but very little piping between. These basins are connected together and to a controlling gate chamber by means of a reinforced concrete conduit. The gate chamber in turn connects by 42 inch mains to the large covered clear water basin and to the city supply mains. It is thus possible to use the auxiliary basins alone, passing all water directly to the city from these, or the water can all be passed through the large clear water basin and thence to the city, or both combinations can be used at once. The system of piping for conveying the water about the plant is so arranged that the water may be stopped at any point in its treatment and passed directly into the city mains. One is enabled by means of bypasses to get a settled water, a coagulated water with or without sedimentation, a settled, coagulated and filtered water, or half a dozen other combinations of water into the mains. Thus, a flexibility of operation is obtainable which is very desirable in any plant.

Perhaps one of the most interesting parts of the Minneapolis filter plant is its large roomy pipe gallery. Unlike most filter plant pipe galleries, it is not necessary to worm one's way about in a mass of dirty, wet pipes. One may dress in his Sunday's best and walk upright from one end of the gallery to the other without encountering the least obstruction. An effort was made to have a



Pipe Gallery, Showing Rate Controllers, Hydraulic Valves, Etc.

clear passage way down the center of the pipe gallery and this was accomplished by hanging the 60 inch influent pipe by steel rods from 18 inch I beams supported by the sides of the filter boxes and they in turn supporting the operating gallery floor. The 24 inch wash water line is suspended from the influent line. The rest of the piping, valves, controllers, etc., is grouped as near as possible to either side of the gallery leaving a clear space 9 feet wide and 7 feet high the full length of the gallery.

All of the valves are hydraulically operated.

The superstructures of the head house and filters are of brick, the inside courses being of the sand lime variety with white mortar joints struck straight with a trowel. The outside facing is built of red sewer brick laid in Flemish bond with red mortar joints rounded back with a round tool at the time of laying. All sloping roof slabs are of 1: 2: 4 cinder concrete except the purlins and girders which are either of steel or rock concrete. The roofs are covered with red asbestos shingles laid on a layer of roofing paper. In the case of the filter house Barrett Specification Roofing was laid on the flat portion while on the head house a 16 ounce copper roof was laid.

The wash water tank or tower is circular in form, 42 feet inside diameter, three stories high, and built entirely of reinforced concrete with a facing of red brick to conform to the rest of the structures. The tank proper or upper story will hold about 135,000 gallons of water but it is seldom that more than 120,000 gallons are placed in it at one time.

The lower story or part of the tank, which is almost entirely below the ground, forms a large sump into which the dirty wash water from the filters is discharged. The middle portion of chamber is used for storage purposes only.

The tank was designed with a large sump on account of there being already a 12 inch to 16 inch drain laid from the reservoirs to the river and it was the desire to use this if possible, instead of going to the expense of laying a larger drain. Without some such arrangement for temporarily taking care of the dirty wash water during washing, the 12 inch drain would be overtaxed and it would be impossible to remove the wash water fast enough to suit operating conditions.

COURSE OF WATER

In operating the plant the water is pumped from the river at the N. E. Pumping Station or the Camden Station by 20,000,000

gallon motor driven centrifugal pumps, through 3½ miles of 50 inch steel pipe into the 75,000,000 gallon settling basin, entering through two inlets, one at the northeast and the other at the southwest corner of the basin.

After a period of sedimentation ranging from two to three days, the settled water enters the controlling chamber by gravity through the 60 inch by 30 inch venturi meter which measures the flow and actuates the chemical feed controllers. From here the water passes through a 60 inch by 48 inch sluice gate into the mixing chamber, receiving in its passage the proper dose of aluminum sulphate, where it is well mixed by passing a great many wooden baffles of around-the-end type.

From the mixing chamber, the water is drawn off into the lower part of the center passage through any two of a number of 48 inch by 60 inch sluice gates as desired from which it finds its way through two 48 inch by 60 inch sluice gates into each of the coagulation basins. After passing through the coagulation basins, the coagulated water is drawn off over the weirs into the upper part of the center passage and finds its way into the main 60 inch influent pipe which is connected to each of the filters by a 20 inch cast iron lateral. In passing through the 60 inch influent line the hypochlorite for sterilizing the water is added but provision is also made to add the hypochlorite to the effluent as well if needed.

After passing through the filters in the usual way, the filtered water passes directly into the auxiliary clear water basins below and thence through a reinforced concrete conduit and 42 inch cast iron pipe to the large covered reservoir. From there it passes through a 42 inch cast iron pipe to the city. As before noted, the filtered water may be passed directly from the auxiliary clear water basins to the city if so desired. Also, a large number of bypasses have been provided and the water may be made to take any one of several courses in passing from the force mains to the distribution mains, but the above course is the one generally in use. The others are for emergency use only.

ATTITUDE OF SPRING WATER COMPANIES

Previous to starting up the filter plant at Minneapolis a number of spring water companies did a thriving business in the sale of water for drinking purposes, charging 5 cents a gallon delivered at the house, but with the advent of the filtered product at 8 cents

per 1000 gallons, always ready in the faucets, the spring water business took a decided drop and the decline has continued ever since.

At first several of these companies tried to unload their stock on the public, but, finding themselves unable to do this in a manner satisfactory to themselves, they at once began an active campaign against the filtered water. Every argument was put forth to show how superior the spring water was to the filtered water. Circulars were distributed about the city informing the public of everything but the truth. The writer is going to quote from one of these circulars to show to what extremes the spring water companies have been driven. In a circular distributed by the Indian Spring Water Company the following appeared:

> "Since the treatment of the Mississippi River water by chloride of lime, alum and filtration, there has developed a vast amount of skin diseases, evidenced by itching and eruption. While we do not make a specific charge that this is due to city water, we are personally persuaded that it is and are willing to submit the matter to judgment of these sufferers after they have ceased its use and resorted to some good, pure untreated table water.
>
> Filtration can remove only the solids or mud. Costly experiments in such cities as Cincinnati and St. Louis show that the filtration of the city water supply caused no decrease in the amount of sickness, and the fact that the water companies in these cities are doing double the amount of business since the filter plant was installed is evidence in itself that the water was not benefited except to make it clear.

How very foolish the above is is evident in itself. St. Louis has not at this time a filter plant of any kind but is building one. The writer was in Cincinnati for over a year after the filter plant was put in operation and knows that the water companies lost business from the start. He also understands that the leading Cincinnati hotels are at present advertising the fact that they use filtered water for table use.

The attitude on the city's part has been to ignore such foolishness as the above and allow the people to be the sole judge of what they wish to drink.

CONSTRUCTION METHODS EMPLOYED

The writer believes that the Minneapolis filter plant is unique in so far as its construction is concerned, being, as far as his knowledge extends, the first and only plant of its kind ever constructed by the day labor system or force account.

Minneapolis, as perhaps most of you know, has for a number of years made all municipal improvements, excepting those pertaining to schools and parks, by the day labor system, employing and paying her labor direct instead of by the contract system. Consequently, when so large a proposition as a mechanical filter plant was proposed, a considerable agitation arose as to the best method of doing the work. This question was settled by agreeing to employ someone familiar with mechanical filter construction and allow him authority in conjunction with the city engineer to buy all the necessary tools and material and carry on the work by force account wherever possible. On August 8, 1910, the writer was retained in the above capacity, but it was not until late in the month of September that it was possible to do any real construction work. Considerable time was spent in organizing a force and getting together a small amount of equipment. Nevertheless, by the beginning of December a considerable amount of work had been done on the settling and clear water basins.

On account of the extreme cold in these latitudes, work was suspended on or about the 10th of December, 1910, and nothing further was done until May of the following year. During the working season of 1911, the work was pushed with vigor on all of the structures. The covering of the clear water basin was finished, the settling basin embankments were raised their full height with the exception of a small gap at the front of the head house and partly lined with the necessary revetment. The head house, auxiliary clear water basins and filter boxes were built up ready to receive the superstructures. During the winter of 1911–12 a small crew was kept busy installing the necessary pipes, valves, pumps, chemical handling devices, and all other necessary machinery that was on hand at that time. In 1912 the coagulation basins, the mixing chambers, wash water tank, and all of the superstructures were finished and made ready for operation.

A considerable delay was occasioned by some of the vital machinery not being delivered on time and a still further delay was occasioned by the nondelivery of the filter sand. The filter structures, themselves, were ready early in October, but it was not until January 10, 1913, that sufficient sand was on hand to operate seven filters. The last filter was placed in operation about one month ago.

Of course, a few leaks were discovered in some of the pipe joints and in two places in the concrete walls, but these were so

small as to interfere in no way with the successful operation of the plant. They were very easily stopped by calking the joints up tighter in the pipes and driving lead wool in the cracks in the concrete walls. If the leaks had occurred in less conspicuous places, they would probably have been allowed to remain with the hope of stopping up in time by themselves, but on account of their being where they were easily seen, it was deemed better to close them immediately. No waterproofing of any kind was used in the concrete, but it was mixed sloppy and well worked while pouring.

The time since starting up the plant has been too short to prepare any tables of results that would be of any value. However, the filtered water has been satisfactory from the first; no typhoid fever traceable to the use of city water has occurred in the city; the people have been saved money and everybody but the spring water companies seem to be well satisfied.

In conclusion, the writer wishes to say that the Minneapolis filter plant was the first plant to be constructed wholly by day labor. Its cost was within the designer's estimate; the actual time the plant was under construction compares very favorably with contract work on similar projects; the quality of work turned out is very good indeed; the performance of the plant under operation is highly satisfactory from a mechanical, chemical and bacteriological standpoint. The people are well satisfied and it is the consensus of opinion that the best method of securing a pure water supply for Minneapolis was finally adopted.

UTILITY AND ATTRACTIVENESS IN ECONOMIC RESERVOIR DESIGN

Description and Design of a Circular Reinforced Concrete Reservoir, 200 ft. in Diameter, 26 ft. Deep, with Side Wall Wholly Above Ground

By Alexander Potter

In the fall of 1910, the writer was retained by the city of Muskogee, Oklahoma, to investigate the existing water and sewerage systems, and to devise methods and means to adapt the existing systems, then overtaxed, to the present and probable future needs of the city.

OUTLINE OF THE WATER WORKS IMPROVEMENTS

Muskogee takes its water supply from the Grand River. The present intake is located in the channel of the Grand River, about 1800 feet above its confluence with the Arkansas River. Two 16 inch cast iron pipes, each 2600 feet long, laid in the bed of the Grand and across the Arkansas River, convey the water to the pumping station. Lowlift pumps raise the water to a 3,000,000 gallon settling basin. The water is then pumped through a 24 inch main, 20,800 feet long, to the city. A standpipe located in the northern part of the city, equalizes the pressure in the town.

The improvements to the water system designed by the writer consist of the replacing of the two 16 inch suction lines by a 4 foot 6 inch intake constructed in rock tunnel, with an intake tower at the upper end; the installation of additional high and lowlift pumping units; the construction of a water purification plant, including a 6,000,000 gallon settling basin, the design and construction of which basin was described in detail by the writer in a paper presented at the thirty second annual convention of the American Water Works Association at Louisville; the construction of the 6,000,000 gallon reservoir with which this article deals; together with the construction of a 24 inch supply main, 12,600 feet long, connecting

the reservoir located on the other side of the city from the pumping station with the existing distribution system.

THE NEED OF A LARGE STORAGE RESERVOIR

The object in constructing the reservoir was twofold; namely, to increase the pressure throughout the town, and to have at all times a large quantity of water available at a sufficiently high elevation to maintain the pressure in the town at times of heavy draft or in case of a serious breakdown of the pumping station or force line.

The pressure in the central portion of the city ranges from 60 to 70 pounds. At times of heavy draft, these pressures cannot be maintained. A standpipe, 25 feet in diameter and 120 feet high, was erected in 1903 to help maintain the pressure in the city. The effect of the standpipe in this direction, however, is very slight, because of the small quantity of water in the pipe at the height at which it is required.

CONDITIONS WHICH INFLUENCED DESIGN OF RESERVOIR

A storage and distribution reservoir, to be effective, should always be located as close to the city as possible; otherwise, too great a fluctuation in pressure will exist in the distribution system. A site suitable for a reservoir exists within the city limits. In the northern part of the city there is a knoll which reaches an elevation of 653 feet above mean sea level. The standpipe was erected on this knoll when the plant was built. In the extreme western end of the city is another knoll, known as Agency Hill, which reaches an elevation of 760 feet, 13 feet lower than the highest water level in the standpipe. The top of this knoll has a hogback shape, and averages about 200 feet in width. This is the only hill available for the construction of a distribution reservoir of the size required.

Good waterworks practice would require a city of the size of Muskogee to maintain a fire pressure of at least 75 pounds. A reservoir with its average water level at the elevation of the surface of the ground on the hill, viz., 760 feet, would give a static pressure of only 69.4 pounds over the central portion of the city. It was decided to adopt some type of construction that would insure a normal water level in the reservoir at least 20 feet above the surface.

The shape of the top of the hill, the size of the reservoir, the necessity of having most of the water stored above the ground, all tended to make the structure one of more than usual interest.

The top of the hill consists of 3 or 4 feet of clay and scattered boulders, underlaid with layers of clay and shale.

Reinforced concrete is practically the only material that could be used to construct a reservoir of the proportion and shape required by the conditions assumed above.

POSSIBLE TYPES OF CONSTRUCTION

A circular shape was decided upon. This shape is usually the most economical, but under the existing conditions, unquestionably so.

To obtain the required capacity of 6,000,000 gallons, a circular tank with its diameter limited to 200 feet requires a depth of 26 feet. To construct a circular tank of these dimensions in which the internal pressure is resisted by the tension in the shell, was considered inadvisable; first, because of the high cost of construction, and second, because of the probability of structural defects developing at the junction of the shell and the bottom. Such defects might permanently impair the value of such a structure as a reservoir.

A circular reservoir 200 feet in diameter will, when filled with water, expand 0.96 inches on the assumption that the steel in the shell is stressed to 12,000 pounds per square inch. This enlarging of the cylindrical shell, as it affects its connection to the bottom of the tank, can be taken care of in one of several ways, all of which are more or less unsatisfactory:

1. By rigidly connecting the bottom to the side and making the bottom a thin section not more than 6 inches thick and sufficiently reinforced with steel so that it can stretch this amount without producing cracks large enough to allow the water to escape.

2. By the use of a watertight expansion joint at the point where the bottom joins the shell.

3. By preventing the expansion at the bottom of the shell.

The third method calls for heavy, massive construction, is correspondingly costly, and is not successful unless the lower portion of the tank is designed with the greatest of care. When this is done, the economy of this type of construction no longer obtains, as the stress in the circular reinforcement depends on the expansion of the shell, which, if prevented by a rigid connection at the bottom, will reduce the working tension in the circumferential bars directly proportional to the amount by which the expansion of the shell is prevented.

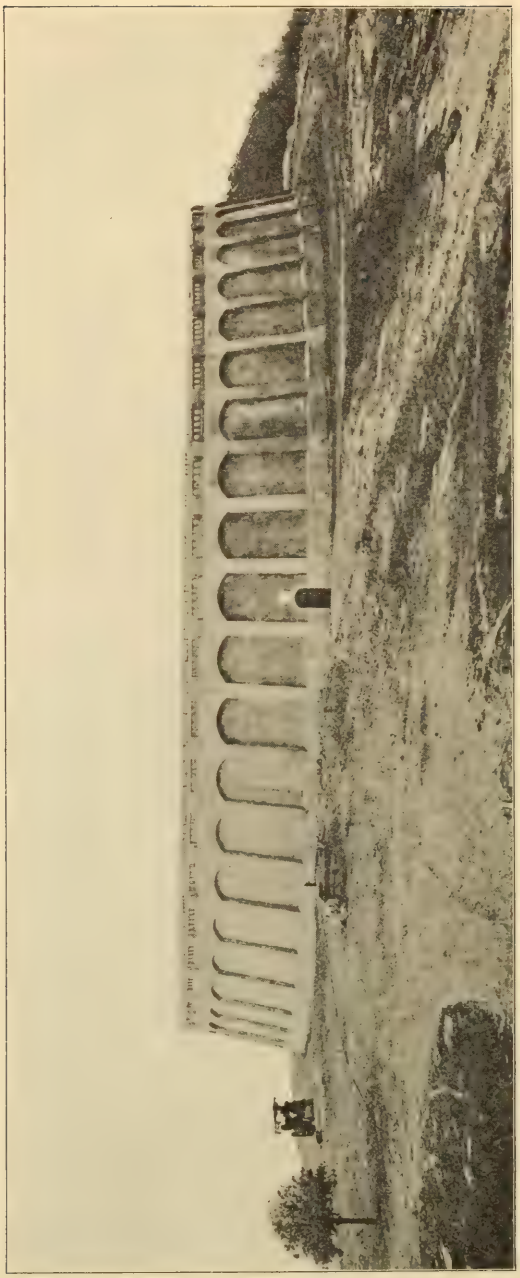


PLATE 1.—ELEVATION OF COMPLETED STRUCTURE

As all of the methods mentioned for overcoming the weakness at the connection of the bottom to the cylindrical shell are more or less experimental in a large reservoir, the writer was opposed to this type of construction. The amount of circumferential steel reinforcement required in the circular type also increases with the square of the diameter. Therefore, the economy in the cost of construction found in the smaller tanks no longer obtains in the larger sizes.

Another type of construction for the side walls of large reinforced concrete tanks is the cantilever section. This type of construction is not, in the writer's opinion, adapted to tanks deeper than 15 feet. In a tank of this type there is always the possibility of hydrostatic pressure developing under the broad base, thereby endangering the stability of the structure.

A third method, and one which has been in general use, is that in which the side walls are supported by buttresses or counterforts. This method of supporting the wall sections is a very economical one for tanks of considerable size in which the depth exceeds 8 or 10 feet. A modified type of this construction, in which the deck is inclined and supported by buttresses, is a very economical one for tanks of greater depth and is the one adopted for the Agency Hill Reservoir described in this paper. The latter type of construction is not adapted to rectangular tanks of considerable depths. In rectangular construction, the corners are very apt to give trouble. Here, the pressures are at right angles to each other, and with the resultant deflections which are appreciable at the top of the tank, also as right angles, it is almost impossible to prevent large cracks from forming at the corners. These cracks are apt to be of such magnitude as to render the structure of little value as a reservoir. This criticism does not hold good when circular or elliptical construction is resorted to.

For the above reasons, the type of construction illustrated in Plate I was adopted.

DESCRIPTION

The reservoir as built is circular in form. 200 feet in diameter on the inside, and 31 feet deep in the center (see Plate II). The walls of the tank are supported by fifty buttresses, radially spaced. The deck is carried straight between the buttresses, thus the reservoir is not truly circular but a fiftysided polygon. For a distance of 10 feet below the water level, the sides are carried down straight;

below this point, the sides are inclined at an angle of 45 degrees. The bottom of the reservoir is a segment of a sphere, with a maximum ordinate of 5 feet at the center.

The shape adopted is one in which practically all of the available water is stored above the surface of the ground. Of the total storage

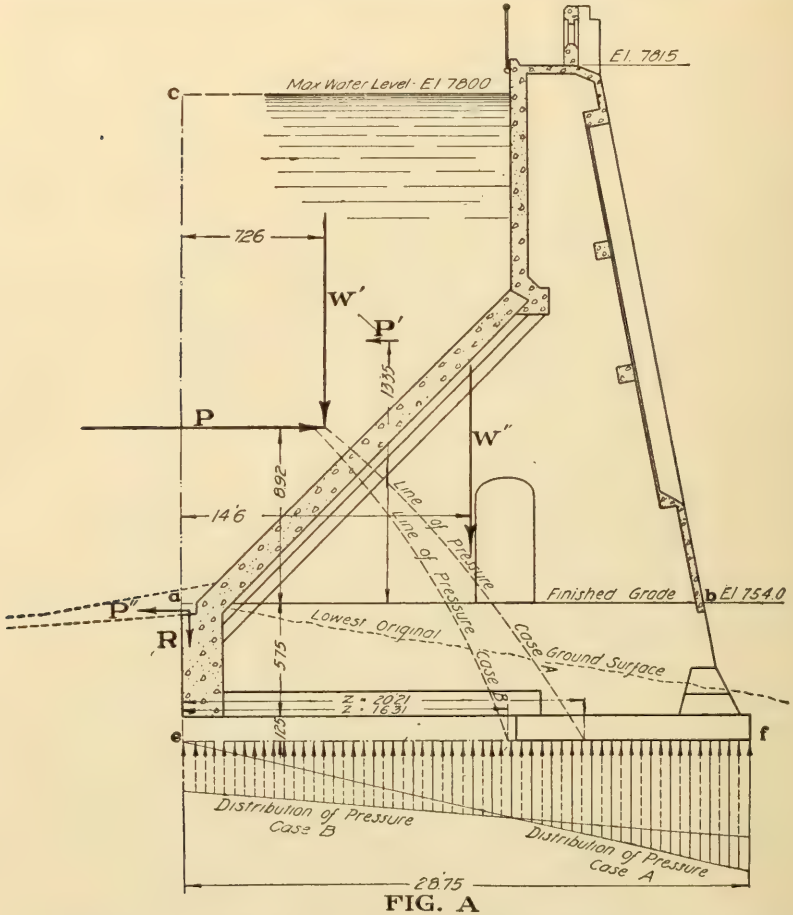


FIG. A

amounting to 6,000,000 gallons, only 580,000 gallons, or 9.7 per cent of the total storage, is below the finished grade, and approximately 40 per cent is stored in the upper 10 feet, thus making it a very effective pressure-equalizing reservoir.

Figure A shows the stresses acting on a portion of the dam subtending an angle of 7° 12′ at the center, all of which is supported

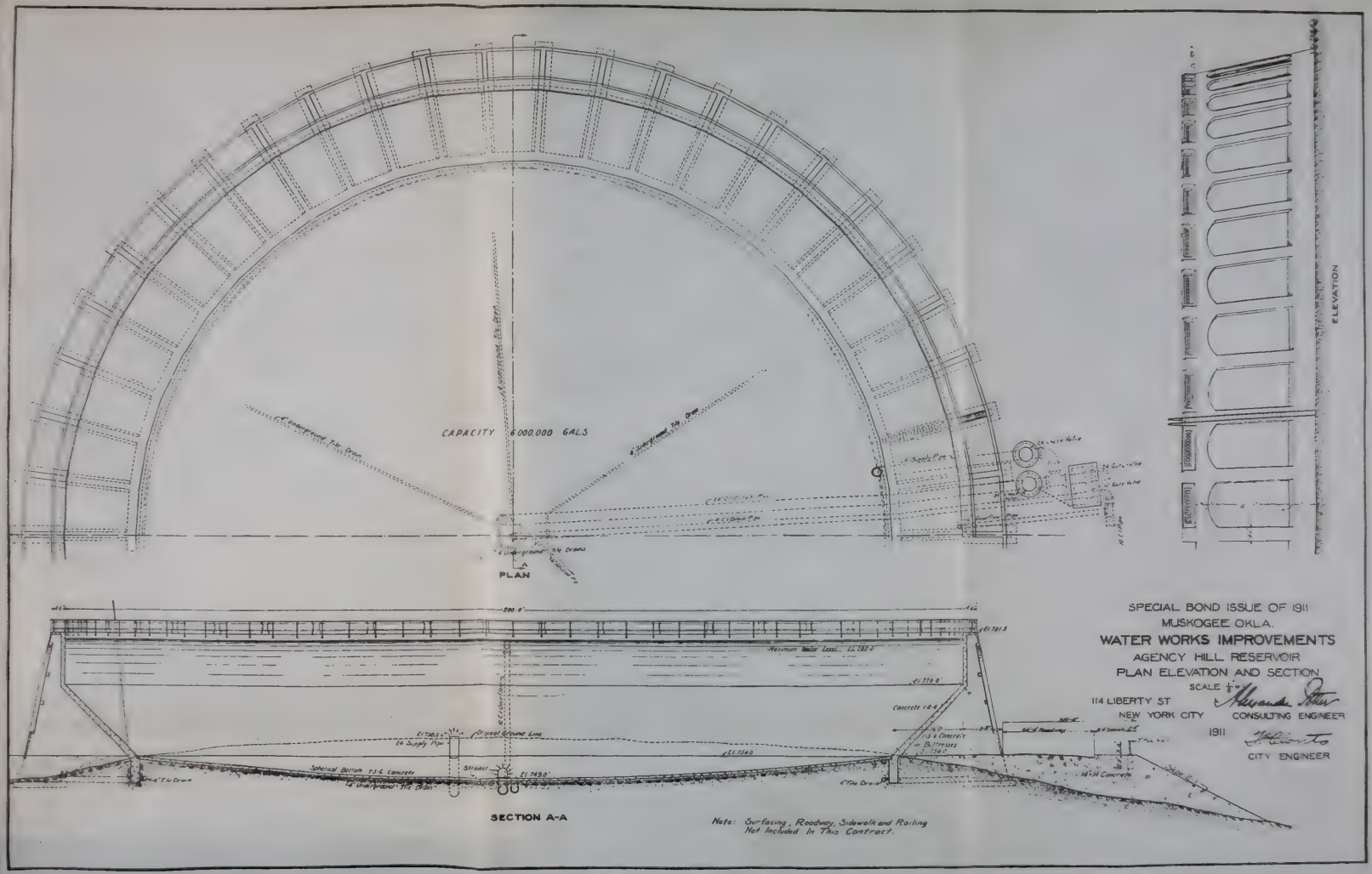

CAPACITY 6,000,000 GALS.
PLAN
ELEVATION
SECTION A-A
Note: Surfacing, Roadway, Sidewalk and Railing Not Included In This Contract.
SPECIAL BOND ISSUE OF 1911
MUSKOGEE OKLA.
WATER WORKS IMPROVEMENTS
AGENCY HILL RESERVOIR
PLAN ELEVATION AND SECTION
SCALE 1/8"
114 LIBERTY ST
NEW YORK CITY
CONSULTING ENGINEER
1911
CITY ENGINEER

PLATE II

by one buttress. In this figure are shown all of the forces acting on the section.

The horizontal component "P" of the water pressure acts radially outward and amounts to 244,880 pounds. Its line of action is 8.92 feet above the line a–b (Fig. A). The total weight of the water—W′—resting on the inclined deck is 218,560 pounds with its line of action 7.26 feet to the right of the line a–c (Fig. A). The prismoidal form of the body of water resting on the inclined deck makes the computations, both for the amount of these pressures and their locations, somewhat involved, and for this reason they are not reproduced in this paper.

The weight of the concrete section—W″—based on 145 pounds per cubic foot of concrete, amounts to 191,000 pounds. Its center of gravity is 14.6 feet from the line a–c (Fig. A).

As several indeterminate factors enter into the computations necessary to determine the line of pressure in the buttress and the distribution of the foundation pressure over the footing course of each buttress, it was deemed best to compute the limiting values of these pressures under the following assumptions:

Case A—Based on the assumption that each section must stand independent of its neighbor.

Case B—Based on the assumption that the various sections are united into a monolithic structure and that all the forces resulting therefrom are taken into account to the full extent that they may be counted upon to develop in the structure.

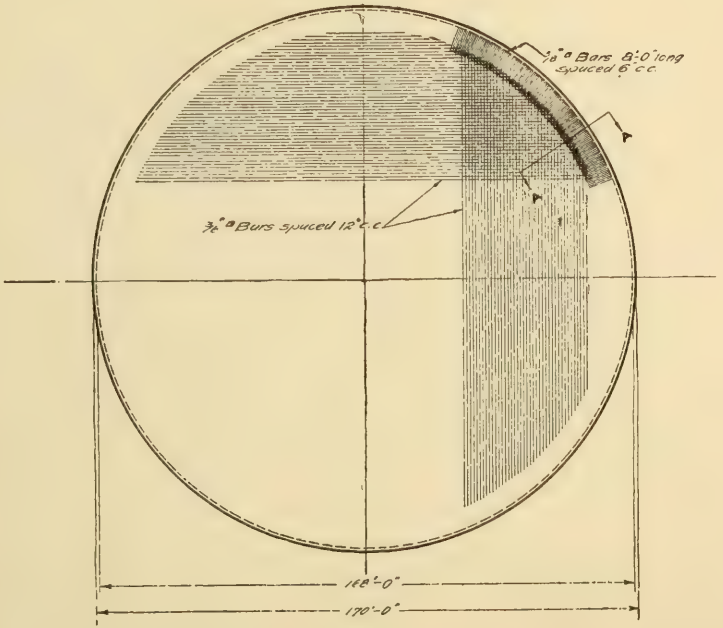
Case A. The point where the resultant pierces the base, e–f (Fig. A), under this assumption, can be obtained by taking moments about the point "e" as follows:

P(=244,880) x (8.92+5.75+1.25)	=	3,898,490
W′(=218,560) x 7.26	=	1,586,700
W″(=191,000) x 14.60	=	2,788,600
	Σ M =	8,273,790

$$z = \frac{\Sigma M}{W' + W''} = \frac{8,273,790}{409,560} = 20.21$$

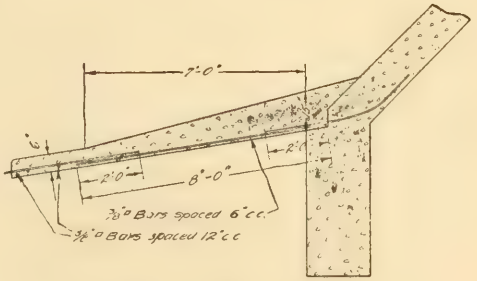
"z" is the distance from the line e–a to the point where the resultant pressure on the foundation pierces the base.

The total width of the base is 28.75 feet. Therefore, the line of pressure falls 1.13 feet outside of the middle third, thus making it appear that there will be considerable uplift at the heel of the but-



PLAN

SCALE 1" = 20'



SECTION A-A

PLAN OF BOTTOM REINFORCEMENT

PLATE IV

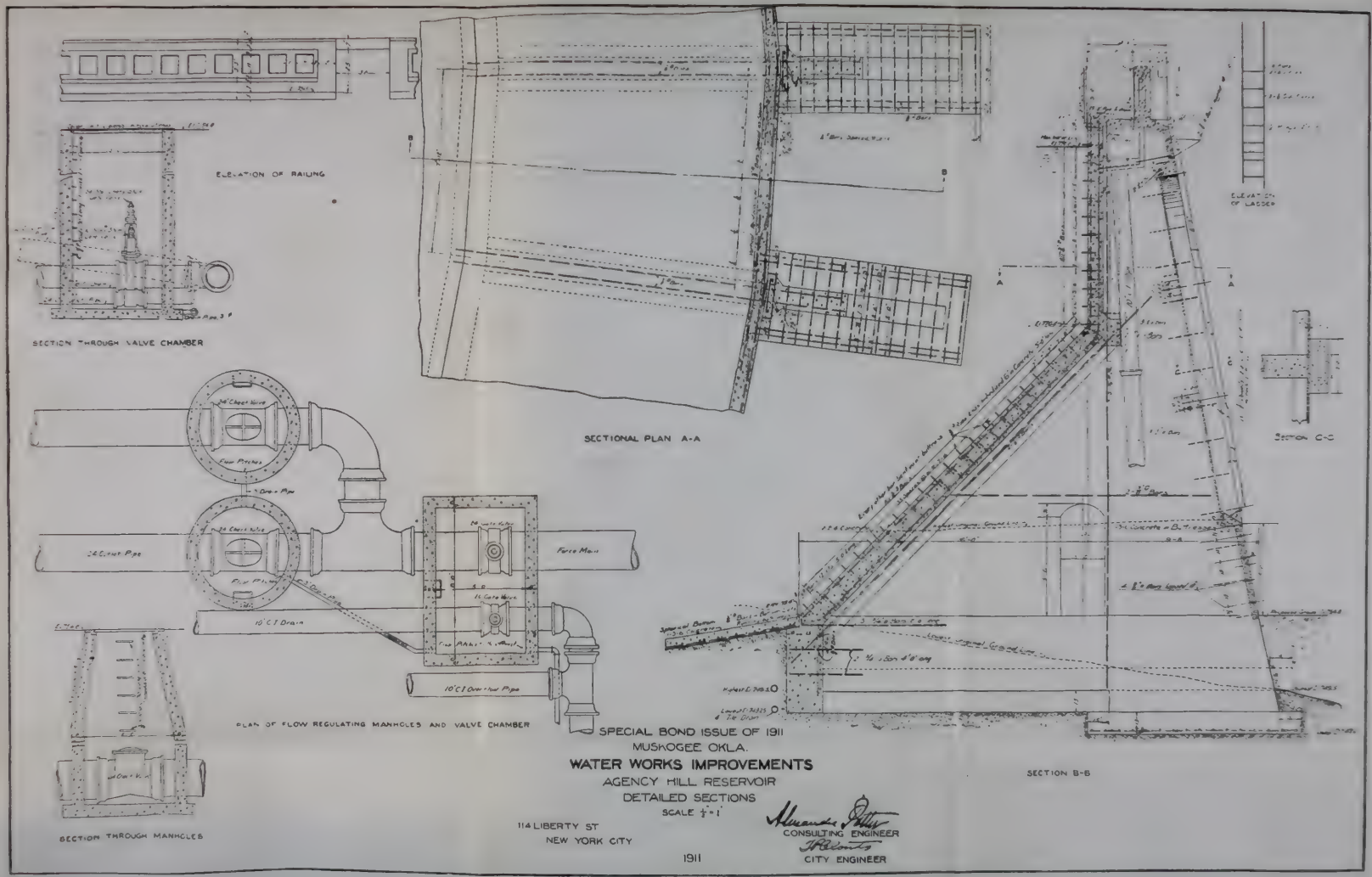

ELEVATION OF RAILING
SECTION THROUGH VALVE CHAMBER
SECTIONAL PLAN A-A
ELEVATION OF LADDER
SECTION C-C
PLAN OF FLOW REGULATING MANHOLES AND VALVE CHAMBER
SECTION THROUGH MANHOLES
SECTION B-B
SPECIAL BOND ISSUE OF 1911
MUSKOGEE OKLA.
WATER WORKS IMPROVEMENTS
AGENCY HILL RESERVOIR
DETAILED SECTIONS
SCALE 1/4" = 1'
114 LIBERTY ST
NEW YORK CITY
1911
CONSULTING ENGINEER
CITY ENGINEER

PLATE LII

tress. This, however, is not the case. A plan of the footing course is shown on Plate III. The total supporting area amounts to 117.65 square feet. Under the assumptions of Case A, the maximum pressure at the toe would amount to 6,727 pounds per square foot, and the minimum to 29 pounds per square foot. There is no uplift whatever at the heel. If, instead of a spread footing, such as shown in Plate III, a rectangular shaped footing of the same area were used, the maximum pressure in the footing would be 7,755 pounds per square foot, and the minimum, a tension of 795 pounds per square foot.

Case B. The line of pressure determined under Case A will not be the true line of pressure in the complete structure. In the complete structure a number of forces are developed, all of which add to the stability. The effect of these on the stability of the structure will be taken up in detail.

EFFECT OF BOTTOM CONNECTION

Prior to placing the concrete in the bottom of the reservoir, further study of the problem indicated a probable weakness in the design of allowing the 6 inch bottom slab to span the refilled excavation made necessary in building the cutoff wall between buttresses. The plans of the bottom, therefore, were revised as follows, and as shown on Plate IV.

To strengthen the structure, the reinforced concrete bottom rests upon and is tied into the face slab by steel reinforcement. The concrete bottom is 6 inches thick and is reinforced with $\frac{3}{8}$ inch bars spaced 12 inch centers. Seven feet from the wall, the thickness of the concrete bottom was gradually increased from 6 inches to a depth of 15 inches directly over the supporting wall. The reinforcement in the bottom immediately adjacent to the wall consists of $\frac{3}{8}$ inch square bars spaced 6 inches at the perimeter. The bottom is tied into the deck by half inch bars, 5 feet long, spaced 12 inch centers.

Figure B shows the connection of the bottom to the sides. In this figure are shown all of the forces that act on the Section A, viz., the weight of the water resting on the bottom with an intensity of "p" pounds per square foot, the supporting pressure of the foundation increasing from zero at the support to a maximum of "p" pounds per square foot, "x" feet distant from the support; R, the reaction per lineal foot of the supporting wall, and P′, the pull per lineal foot exerted by the side walls. This construction would

add appreciably to the stability of the buttresses in transferring the line of pressure nearer to the center of the wall.

In Figure B, the distance "x" is limited by the strength of the bottom slab. Assuming a fibre stress of 20,000 pounds per square inch, as the limiting stress that can be developed in the steel without permanently impairing the strength of the structure, we obtain a value of 6.28 feet for x and a value of 3,400 pounds for R. The force T is developed in the $\frac{1}{2}$ inch bars spaced 12 inch centers along the perimeter of the bottom and can reach 5,000 pounds per lineal foot without injury to the structure.

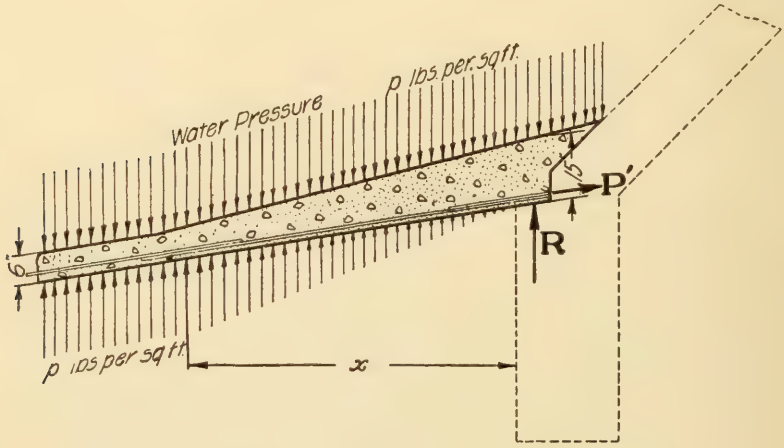


FIG B

When the work was well under way a new city engineer was chosen and placed in actual charge of the construction.

The need of some additional reinforcement of the bottom at this weak point of connection was apparent when pointed out. As a substitute therefor, all the excavated material disturbed by the construction of the toe of the deck slab was removed and the space filled with plain concrete and the original thickness of the bottom maintained. This not only required more concrete, but it effectually destroyed the function of the drain laid at the foot of the wall to prevent hydrostatic pressure from developing under the structure.

EFFECT OF CONTINUITY OF CIRCUMFERENTIAL REINFORCEMENT ON THE STABILITY OF THE STRUCTURE

The circumferential reinforcement of the structure consists of sixty five $\frac{3}{4}$ inch bars, eleven $\frac{1}{2}$ inch bars, and six $\frac{3}{4}$ inch bars, giving a total cross section of 39.97 square inches. All of this reinforcement is lapped sufficiently at all connections so that the steel reinforcement of the shell can be considered to be practically continuous. As the shell expands under the internal pressure, this steel reinforcement is subjected to tension, thereby resisting directly a certain amount of internal pressure. The writer has every reason to believe that the diameter of the tank when filled with water will increase by $\frac{1}{2}$ to 1 inch at the top. This expansion of the tank under pressure produces a stress of from 6250 to 12,500 pounds per square inch in the circumferential steel reinforcement.

Assuming the average stress in the ring tension due to the circumferential reinforcement to be 6000 pounds and to increase from 3000 pounds at the bottom to 9000 pounds at the top, the total outward pressure per lineal foot of tank thus resisted by the steel, amounts to 2585 pounds. This is obtained from the formula,

$$T = pr$$

where T = ring tension = 6000 x 39.97 = 239,820 lbs.

p = total hydrostatic pressure per lin. ft. of perimeter resisted by ring tension.

r = radius of tank, 92.75 ft. measured at the same height as the resultant line of action of the horizontal water pressure.

The height at which the force "p" acts can only be approximately determined. The center of gravity of the steel reinforcement is 11.5 feet above the line a–b and with the assumption as to the distribution of the pressure, the line of action of "p" is about 13.35 feet above the line a–b.

In Figure A are shown all of the forces acting on a portion of the dam, supported by one buttress, when this section is considered to form a part of the complete structure. The additional forces acting on the section, due to the rigid connections, are P′, R and P″.

P″ represents the radial tension that may be developed by the steel reinforcement connecting the bottom with the inclined deck. The value of P″ may reach 5000 pounds per lineal foot, or 52,900 pounds per buttress, without injury to the structure.

R represents the reaction of the bottom on the supporting wall. This may also attain 3400 pounds per lineal foot or 35,900 pounds per buttress.

The pressure—P′—under the assumptions made, amounts to a maximum of 2585 pounds per lineal foot of circumference, or 31,600 pounds per buttress.

Taking moments about the point "e" of all the forces acting on the section, under case B we have:

P = 244,880 x 15.92	+3,898,490	
W′ = 218,560 x 7.26	+1,586,700	
W″ = 191,000 x 14.60	+2,788,600	
P′ = 31,600 x 20.35		−643,060
P″ = 52,900 x 7.00		−370,300
	+8,273,790	−1,013,360
	−1,013,360	

$$\Sigma M' = 7{,}260{,}430 \text{ ft. lbs.}$$

$$\Sigma V' = W' + W'' + R = 445{,}460$$

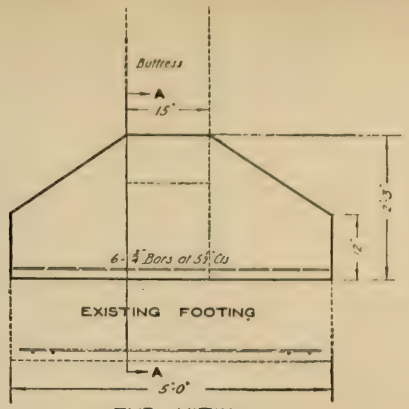
$$z = \frac{\Sigma M}{\Sigma V} = 16.31$$

Under Case B, the pressure line cuts the base 16.31 feet from the heel, well within the middle third. This gives a foundation pressure ranging from 4962 to 2544 pounds per square foot.

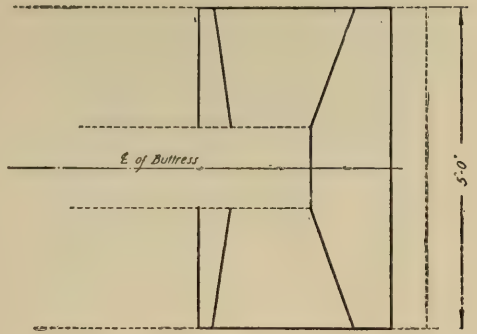
The foregoing computations show that the pressure at the toe of the buttress footing may range from 4962 to 6727 pounds, and the minimum pressure at the heel from 29 to 2544 pounds. These pressures are conservative for the character of the foundation upon which the footings are placed.

The buttresses, which are radially spaced, are 15 inches in thickness. At the point where the inclined deck starts there is considerable tension on the side of the buttress nearest the water. This tension is taken up by three $\frac{7}{8}$ inch square bars at a unit stress in the steel of 9000 pounds per square inch, making full allowance for the weight of the section; ignoring this, the stress in the steel will be 15,000 pounds per square inch. Two $\frac{7}{8}$ inch square bars are carried up along the face of the incline of the buttress to take care of any possible tensile stresses, especially at the upper end of the incline where these stresses may be considerable.

SECTION A-A



END VIEW



PLAN

DETAILS OF FOOTING REINFORCEMENT

The face of the buttress upon which the deck rests is corbeled out to 30 inches. The corbel is reinforced by two $\frac{5}{8}$ inch square bars tied together by $\frac{3}{8}$ square ties spaced 12 inches centers. These ties serve both the purpose of reinforcing the corbel against cantilever action developed by the deck resting on the outer ends of the corbel and preventing the splitting of the buttresses.

When the structure was about half completed, the writer discovered an error that had crept into the plans which called for $\frac{3}{8}$ inch square bars in the spread footings of the buttresses in place of $\frac{3}{4}$ inch square bars as required by the computations. The footings as constructed in the opinion of the writer do not give a sufficient factor of safety in adequately distributing the pressure over the area assumed in the design, and it was therefore deemed highly advisable to reinforce the spread footings. Plate V illustrates the method suggested by the writer for reinforcing the footings.

This method required the cutting out of each buttress already constructed, a section, marked A–B–C in this plate, and placing upon the footing a reinforced concrete beam 3 feet wide on the base and about 27 inches deep under the buttress and 12 inches deep at its outer end. This beam was to be reinforced with six $\frac{3}{4}$ inch square bars.

To obtain a good bond between the old buttress and the new work, it was proposed to maintain a head on the semiliquid concrete so as to force it into the buttress and to maintain this head until the new concrete had obtained its final set.

The writer regrets to state that the city officials failed to appreciate the importance of strengthening the footings, which could have been done at a nominal cost. In refusing to comply with the plans as developed by the writer, they assumed all responsibility for the structure. There is always a possibility that one of the buttresses may settle sufficiently to impair the usefulness of the structure as a reservoir. Had the writer's suggestion been carried out, it would have effectively reinforced the spread footing so as to enable it to properly distribute the pressure over the foundation.

CONSTRUCTION OF DECK

The deck, with the exception of the top, is not tied into the face of the buttress by steel reinforcement. The vertical portion of the deck is 10 inches thick. The thickness of the inclined portion varies from 12 inches at the top to 15 inches at the bottom. The steel reinforcement is stressed to an average of 5200 pounds per

square inch in the vertical portion of the deck, and to 10,000 pounds in the lower or inclined portion. The deck of the reservoir is constructed as a monolith; no expansion joints are used. This type of construction throws additional tension upon slab reinforcement, especially in its upper portion. Provision has been made, in the design, for this additional stress by using a somewhat lower working tension in the slab reinforcement than is otherwise necessary. A widening of the diameter of the tank at the top, of as much as an inch, will increase the stress in the circumferential reinforcement to 17,200 pounds per square inch.

Attention is called to the connection of the inclined to the straight portion of the deck. This joint, which is naturally a weak one, has also been made a construction joint. It has been strengthened by a 12 inch by 16 inch concrete beam reinforced with four $\frac{3}{4}$ inch square bars.

HYDROSTATIC UPLIFT

In this article no mention whatever has thus far been made of the possibility of hydrostatic pressure developing either under the concrete bottom or against the curtain wall, and thereby affecting the stability of the structure. This is guarded against by underdraining the spherical bottom with four and six inch tile drains. Five 4 inch lines of drains are laid radially and drain to a sump at the center of the reservoir. From this point a 6 inch drain is carried radially outward to a free outlet on the hillside. A circular line of 4 inch tile drain is laid entirely around the outer edge of the spherical bottom just above the footing of the 24 inch circular cutoff wall.

With these provisions, it is almost impossible to conceive of hydrostatic pressure developing to an extent to make it necessary to take it into consideration in the stress analyses. Under the worst possible conditions, with all the underdrains clogged, the hydrostatic uplift is limited to the bottom of the reservoir and the footing of the 24 inch wall, and even then the effect of it on the stability of the structure is negligible.

ARCHITECTURAL TREATMENT

To improve the appearance of the structure, the buttresses are widened out to 3 feet at the back, and between them a concrete curtain wall, 4 inches thick, is carried up for a distance of 4 feet above the finished grade (see Plates II and III). Between the tops of the buttresses, concrete arches are sprung. Each arch has a rise of 3 feet and a clear span of 3 feet less than the distance between

the buttresses. The recess thus formed is filled at a depth of 12 inches with a thin curtain wall of stucco placed on hyrib. At intervals of 5 feet 7 inches, the hyrib is supported by reinforced concrete beams. A concrete walk, 2 feet 8 inches wide, extends entirely around the reservoir. On the outside of the walk a concrete railing in conformity with the architectural treatment of the reservoir is built. The false construction just described gives the reservoir a pleasing appearance of massiveness.

A driveway, 33 feet 6 inches over all, extends entirely around the reservoir.

PIPING AND DRAINS

The water enters the reservoir through a 24 inch line. The outlet is located at the center of the reservoir and is of the same size. Circulation is maintained by two check valves, one in the inlet and the other in the outlet, so arranged that the direction of the flow in these pipes cannot be reversed.

The overflow is located 18 inches below the top of the tank. The overflow pipe is 10 inches in diameter. A 10 inch cast iron pipe, with its inlet in the lowest part of the spherical bottom and its outlet on the hillside, drains the reservoir.

MONOLITHIC CONSTRUCTION

Some question may be raised as to the economy of constructing a reservoir of the size described without expansion joints. The principal advantage that can be gained by monolithic construction is a general increase in strength. In a large structure, this increase in strength is by no means as great as a casual inspection leads one to believe. It is obtained only at a sacrifice. The stresses in the deck, when built continuous, are no longer static determinate quantities, and their amounts cannot be determined with any degree of accuracy. The stresses developed in the deck acting as a beam are also increased a more or less indeterminate amount by the expansion of the shell under pressure. For these reasons, comparatively low unit stresses must be used in designing the deck. The gain in strength due to continuity of deck construction practically decreases as the square of the diameter in a structure of the type described. The increase in strength due to continuity of deck construction in large tanks is therefore very small.

WATERTIGHTNESS OF THE STRUCTURE

Under ordinary conditions, the writer is opposed to the use of waterproofing ingredients or waterproofing applications, as both add considerably to the cost of concrete work. It is far better to put the value of the waterproofing materials into the concrete work itself by adding more cement. In general, the use of waterproofing ingredients or applications tends to poor construction work, the contractor counting upon the waterproofing to materially help out careless construction.

The only waterproofing called for in the specifications under which the reservoir was constructed were two coats of neat cement wash to be applied with a whitewash brush on the inside of the basin, the second coat to be applied before the first one had had time to get very hard.

Before the final acceptance of the work, the contractor was called upon to render the structure watertight if leakage developed in the basin in excess of 5 gallons per minute. The reservoir has been filled for a number of months to within 10 feet of the top, and the leakage, as measured at the outlet of the underdrains, at no time has exceeded half a gallon per minute. No leakage whatever is visible on the outside of the shell.

Specifications permitted the use of horizontal construction joints, and on eight bays such joints were used. The unfinished surface of these was always left in as rough a condition as possible, but was never roughened up after the concrete had partially set. The writer's experience is that this roughening often loosens the stones in the partially set concrete, but not sufficiently so that the loose stones can be removed by brushes, a condition which is apt to impair the water tightness of the structure.

To start a day's work, the old concrete surface was thoroughly cleaned with wire brushes and water, and a semiliquid mortar mixed in the same proportions as the mortar in the concrete was poured over the old work to a depth of half an inch. This method has given good, watertight horizontal construction joints.

Vertical construction joints were permitted only over the buttresses as such joints are very difficult to make watertight.

COST OF THE STRUCTURE

The following is a detailed statement of the final estimate of quantities and total cost, together with the unit prices:

7,655.8 cu. yds. earth excavation	@	$0.55	$4,211.24
2,797.0 " " rock "	@	1.70	4,754.90
70.0 lin. ft. 12" V. S. pipe	@	0.70	49.00
145.0 " " 6" " " "	@	0.20	29.00
281.5 " " 10" C. I. pipe	@	2.00	563.00
179.5 " " 24" " " "	@	5.40	969.30
117.0 " " 3" wrought iron pipe	@	0.50	58.50
931.0 " " 4" drain tile	@	0.12	111.72
1–10" gate valve	@	30.00	30.00
8,577.0 lbs. cast iron specials	@	0.05	428.85
4,032.6 bbls. cement	@	1.50	6,048.90
338.0 lbs. wrought iron	@	0.05	16.90
1,762.34 cu. yds. No. 2 concrete	@	7.00	12,336.38
2.0–24" check valves	@	200.00	400.00
1,166.66 cu. yds. No. 1 concrete	@	9.00	10,499.94
204,722.0 lbs. reinforcement	@	0.0425	8,700.68
50 corbel forms	@	17.25	862.50
9,236.5 sq. ft. stucco	@	0.15	1,385.48
Lumber, nails, labor, outside finish (lump sum)			1,100.00
320.0 cu. yds. concrete (extra)	@	3.00	960.00
658.0 lin. ft. parapet wall	@	1.40	921.20
1–$\frac{1}{2}$" pipe rail (lump sum)			627.00
Framing door	@	30.00	30.00
Making door	@	15.00	15.00
1 strainer	@	7.50	7.50
Nipples			25.00
Stairway	@	130.00	130.00
630 lin. ft. concrete curb	@	0.25	157.50
Total			$55,946.99

The reservoir was built on the summit of a hill about a mile from the nearest railroad station. All water used for concreting had to be carted up the hill, a distance of about a mile.

The contractor's profit on the work approximated 20 per cent, indicating a reasonably economic reservoir, yet one which presents a very attractive appearance.

A HISTORY OF THE ORIGINAL PUBLIC WATER SUPPLY OF THE CITY OF MEMPHIS, TENNESSEE.

By William L. Cameron.[1]

Prefaced by an explanation and a chapter of ancient history.

EXPLANATION

As all of the original members, with the exception of one, who composed the company to which is due the credit of having constructed a much needed public water supply for the city of Memphis, have "passed over" it is due to their memory that they should have the credit of having been men of enterprise, public spirit, and ability. The original proposition would have justified their expectations but for the most unforeseen combination of circumstances. The very first year, 1873, the works began operations proved, from a financial point of view, one of "national" disaster, and locally, they were confronted by an epidemic of yellow fever. The quality of the water that the writer has "in a humorous vein," attempted to describe was a great handicap, although an Eastern *expert* had analyzed it and reported it as the *third* best water in the United States, the citizens of Memphis were slow to subscribe to the verdict. Revenue therefor from private custom was small for the first year. The very competent financial agent had provided bonds having inscribed upon the face of same a liberal contract made with the city for fire hydrant rental.

He had used these bonds as collateral for material, machinery and money with which to construct the works, the arrangement being that the coupons became the property of the loaners (the writer here alludes to the original incorporators).

Well, to make a long story short, pay day came, the city refused to pay its first installment; in fact, had nothing with which to pay,

[1] An official of the Company from its inception in 1872 up to 1891, and intimately connected with the construction and management of the Company's plant, and who had an appreciation and knowledge of the object and ideas of its original promotors.

bond interest, bills, etc. and cash loans, began to fall due, and as the projectors had put all their money into the organization, and expenses of two years,—litigation with the city,—etc., there was nothing with which to meet these accounts due. Some of my readers,—promoters of enterprises constructed upon credit, and the brains and ideas of the projectors, can understand that it was a short road into the hands of a receiver and our enterprising citizens were, as has been related, relegated to be "lookers on" at the struggles of the child they had brought into the world; what they might have done for its future health and growth is, of course, problematical, yet they should have due credit for the enterprise of undertaking what has turned out to be one of the finest water-works plants in the country.

To be sure, the managing receiver had the water and its quality on his hands and had much interesting experience in his efforts to filter, subside, or clear same in any manner. An oldtime house filter made out of a barrel with coarse gravel, fine gravel, charcoal, felt, etc., would in a very short time develop into a concrete mass through which not even clear water would percolate and the effort to precipitate the deposit developed would take *two months*, and then there would be left a yellow tinge. Alum or lime would overcome, assist and quicken the process of precipitation but the amount one would have to use was too great and affected the water. The manager threw open the job of cleaning the water to several filter companies and considerable time and money was uselessly expended. Yet in spite of the undesirable quality of the water the six years of the receivership developed quite a fine business for the property, a sum in cash and bonds being turned over to the court of some $50,000 as the net results, besides more than that amount being expended in extension of mains and other permanent improvements to the plant. During this period there occurred many drawbacks, however, to the success of the enterprise, the most serious being the very terrible yellow fever epidemic of 1878 and 1879 and a prolonged financial depression so that a property worth, even to replace, over $300,000 brought only $155,000 when sold in 1880. This low price was largely due to the fear upon the part of outside investors of the return of the dreaded yellow fever. This, however, was a false alarm. The Waring system of sewers was inaugurated by Colonel Waring himself, and the rapid connection of all premises to same came to be not only the salvation of the city but resulted in making of the waterworks property a very

valuable investment. Like all men who know nothing of machinery and whose investments heretofore have been along the line of so much *per cent*, on so much *cash*, the new owners were slow to "become wise" to the fact that machinery would wear out, and would say, "Why, it all seems to be running smoothly." The argument on the part of the superintendent that these pumps were constructed to pump *three* million gallons of water per twenty-four hours and had been pumping *four* million for some years and when broken down had to be repaired at a very unusual expense, night and Sunday work double wages, met with a calm smile from the stockholders, who were drawing some twelve per cent on the stock, and when he got "elbow to elbow" with his brother directors at a meeting of the board, it was a hard proposition to move that body towards *new machinery, larger water mains*, and an attempt at a better water supply.

The writer of this paper, not to appear too personal, stood in the breach, and gave the best years of his life in the attempt to give a satisfactory water supply to the people of Memphis, Tennessee. On the Board of Directors of that company one man always stood for improvement and in so far as his influence went, he always used it to that end. At last the crisis came and something had to be done. When the plans, approved by the consulting engineer, were presented to the board, involving an expense of, say, a million dollars, this gentleman, Major G. W. Macrea—a high type of the farseeing business man, imbued with the feeling that one must also remember "to do unto others as we would they should do unto us,"—this gentleman, a large stockholder and a force of power in the company, said, "I approve the plans and say, let us go right ahead and construct a satisfactory water works. I do not care if I do not secure a dividend in years, we *must* give these people good water and a plentiful supply with fine pressure." To this broadgauged man who, in spite of opposition from most of his associates at the time, the people of Memphis are indebted in a large measure for the handsome water works plant they are now enjoying and the company as individuals,—in spite of the rather narrow view of some of them at a certain time,—reaped a magnificent benefit, for the improvement of the water supply aided the growth of the city, as it does in every city, and the growth of the city made the very handsome success of the enterprise a certainty from a financial point of view.

Chapter I

Many years ago, prior to the "ken" of the "oldest inhabitant" the village of Memphis, Tennessee, had suffered in its growth from its bad reputation as to health and the shortness of life as experienced by many of its early inhabitants. In some instances this early departure of a citizen was caused by the playful practice of another citizen with a "bowie-knife" or revolver, yet much was seemingly due to the miasma wafted across the Mississippi River from the swamps of Arkansas just opposite. At that early day the gay and festive steamboat was much in evidence upon the river and Memphis was a favorite port for same to enter. Many of the male citizens would visit the vessels. Upon the occasion of a certain call made by some of these gentlemen the subject of the health conditions, its causes and its evil effects upon the people in general—were discussed. The officials of the vessel listened to this "tale of woe" for some time when finally the captain of the boat advanced an "idea." He said: "I have been sailing these waters for forty years and experienced in the early days of my service the evils you complain of; but for the last thirty years I have been taking a 'medicine' that has given me much satisfaction and which seems to be an antidote for this trouble. Will you gentlemen accompany me to my dispensary? I shall give each of you a dose of this medicine and during your present visit on board you can repeat the dose at stated intervals, with the privilege also of returning each day I am in port to continue the experiment."

It is needless to say that the Committee, *to a man*, cheerfully fell in to this arrangement. Before the vessel left the captain kindly furnished one of the visiting gentlemen with a sample bottle of the medicine. In a very short time "dispensaries" for the sale of same could be found in quite large numbers scattered through the then village. A great improvement in the health and condition of the people, especially the male portion, was soon discovered. There is no record as to what portion of the female inhabitants resorted to the remedy. At that time the ladies of a community were not given to as much publicity as at present.

This happy and satisfactory condition continued during many years, the inhabitants finding such good results from a moderate use of the "medicine" and that it not only seemed an antidote for the effects of the miasma but caused one to have a feeling of exhilaration of the whole system, they were tempted to, and did,

double the dose each day. They may also have been induced so to do from a friendly desire to encourage and repay those kind gentlemen who had invested their capital in furnishing elegant and comfortable quarters where the seeker for "medicine" could enjoy his ease while he imbibed his dose. Some added a fine lunch, without extra cost to the patron, others even furnished music, the longhaired gentleman who presided at the "instrument" being protected from a possibly freehanded patron by a sign similar to those in vogue in later days in far western places: "Don't shoot the musician; he's doing the best he can."

Years had elapsed when these people of the "Bluff City" realized that like everything else in this world of ours, complete happiness and security from trouble was evidently not to be attained. The use of this "medicine" seemed, after a few years, to have in some manner disorganized the lining of the stomachs of the people.

Chapter II.

On the banks of a raging river named "Wolf" which emptied into the Mississippi about a mile north of the city of Memphis, there lived an old man; we have arrived at the year (say) 1870. This old man had been born in the cabin located on this classic stream and his seventyodd years had been spent right there. He had bathed in, cooked with, and drank from the waters of the Wolf since he left the milk at his mothers breast. He had studied and analyzed it in every way. Among the numerous properties he discovered were the following: In the thickest portion of the deposit he found an ingredient which, when applied by a whitewash brush upon his board fence had the appearance of a fine shining yellow paint that seemed to firmly adhere to the fence. The rains and snows of many seasons appeared to have no effect; in fact, after a long continued sun upon it, it seemed firmer than ever.

This old gentleman, in addition to being a farmer in a small way was also engaged in making bricks. During a specially high stage of the Wolf he tried another experiment and discovered that there was another property of value in the sediment, a sort of fine cement. Taking advantage of a forcepump connected with the river, he pumped his brick molds full of water from same; after leaving the molds in the sun for a few days he turned them out and much to his delight discovered fine, hard cement brick already colored to a becoming yellow. There seemed to show

through the outside polish the remains of caterpillars and dead oakleaves and the bricks emitted a strong odor of caterpillars. Yet, in the many years during which he had both drank and washed, etc. etc. in using this water he had become accustomed to this odor and even a slight taste in same, suggesting "caterpillar" so he did not mind this especially and it did not depreciate the value of the other properties.

He now had a fine yellow paint and an excellent material to make the best of cement brick, simply by pumping from the Wolf River. This old fellow, although much engaged at home found time to visit what had now become a city, and would join some of the men at the resorts spoken of in the first chapter. From conversation with citizens at these places in the city he became informed of the trouble beginning to be experienced by them. Living as he had for so many years close to the water he had suffered, as had his fellows in earlier times, from the miasma, and, like them had fallen into the use of the "remedy;" in fact, always kept a five gallon "runlet" in his cabin. After his return from one of these outings into the city, one night he began to cogitate: "I take as much, or perhaps more of this medicine than the average citizen yet feel no effects in my stomach; to be sure, it seems larger yet most men grow that way as they advance in years." Suddenly an idea came into his brain, which he grasped at once. "By George! *it is the cement in* this water, I think, that has formed an impervious coating and the medicine, therefore, to *me* is harmless." This old man, in spite of his primitive surroundings and rough personality, had a fine mind and a warm heart and was full of philanthropic intentions to act for the good of his fellowman; added to which was a true amount of appreciation of what was also due to his family and himself.

This old man, after much thought on the matter of the "medicine" its unpleasant effect upon the health of the citizens and his happy "idea" as to a remedy, became imbued with another large idea, too great for him singly to tackle. Mr. C— (now that we have found him to be a man of ideas and one who may in the early future become one of "affairs" may be dignified by bestowing on him his proper title); Mr. C— had four very intimate friends, men with whom he had frequently associated over a glass of "medicine" and a pipe of tobacco. He dropped a line to each of them, writing them to be with him at his home upon a certain day; replenished his "runlet" and sent his wife to visit her sister,—who resided at a

distance that would make it impossible for her to be home again for some hours.—The gentlemen appeared. Mr. M—, the financial manager of a large cotton and grocery company; Mr. T—, his partner, Mr. B—, a prominent lawyer, Mr. G—, the owner of a large foundry and machine business. Quite a congenial party all and each believers in the "medicine" and yet sufferers of late years from an uneasiness in the region of the stomach. As soon as these gentlemen had assembled and had tapped the "runlet" and filled a pipe, Mr. C— opened up his "idea", cited his long cogitation on the subject matter, the conclusions he had arrived at and finally gave voice to the large proposition he desired his friends to join in with him to carry out. He stated that knowing each one as he did he knew that each was filled with love for his fellow men and a philanthropic desire to do for said fellow men all within his power.

The lawyer, a man of quick speech although in private conversation not addicted to much talk, said, "Let it go at that. What is the proposition?"

"The proposition" said Mr. C— "is for us five to form a corporation to be known as the 'Memphis Water Company' our object being to supply from this, the Wolf River, water for the public. When the people begin to drink this water it will so act upon the stomach as to form a coating making it impervious to any evil effects from the 'medicine'. The people of Memphis have become so accustomed to the use of this very agreeable 'medicine' and its exhilarating effects that it is evident to my mind, and I judge them all by my own feelings on the subject, that it will be difficult, if not very nearly impossible, to prevent their continuing the use of it. When we have constructed these water works and opened out to them the sure effects of the water, if drank by them, all will wish to have connections to the mains of our company and besides the main object,—which is a good to our fellow man,—having been obtained, we *may* make a considerable sum for ourselves by the enterprise." Mr. C— then described the special experiments he had made, to which the water could be successfully applied in addition to the thousand and one for general household use. Fire hydrants could be rented to the city, etc.

Chapter III.

A few months after this important meeting the Memphis Water Company was chartered, the five gentlemen mentioned above being named as charter members of the company. At the organization meeting Mr. C— was made president of the company. A young man of *fine* abilities, (that is, the writer), was elected secretary, the only *salaried* position at that time. Mr. B— was made attorney for the company, Mr. M—, financial agent, —a very necessary officer at the beginning of so costly an enterprise.— Mr. T—, treasurer, Mr. G—, vice-president. All five of these gentlemen were directors.

An interval of some two years was occupied in a legal battle between the company and the city government of Memphis. The latter claiming that it had the exclusive right to construct water works and to supply the city. This matter was finally settled between the parties.

On, or about the Spring of 1873 the Memphis Water Company commenced to pump that "fluid" for which the facetious citizen, in after days, had many names; principally "caterpillar soup." At that time the newspapers of the city took opposite sides in their columns as to the merits of the new company. A large morning paper was profuse in its advocacy of the water works. Each morning it published fulsome articles of praise in its favor.

People began to visit the office in order to enter their names as patrons of the company. Most of them said they would only have a yard hydrant at present, explaining that they did not feel like mortgaging their homes to pay for plumbing—other fixtures. The official had an idea that there might be in their minds an inward fear that after a bath in this water they might come out the yellow color of a Chinaman. They would also take "with a grain of salt" the advertised benefit to be derived from drinking the "stuff." One lady having a hose attached to her hydrant appeared at the office and lodged a complaint that her vines, bushes, trees, etc. etc. (or the leaves of same) seemed to be covered by a shining yellow coat finely cemented and which, had not, up to that time —although more than ten days had elapsed since she sprinkled them, come off. Gentlemen, who were neatly costumed in white flannel or linen duck with Panama hats, would call at the office and show yellow spots upon their clothing, asserting that same had been caused from drops of water squirted from a nozzle held in the hands of one of our patrons.

These were simply initial complaints; the future developed to the patient and most polite official at the office that his troubles had just commenced at that early time. Adding to the troubles of the new company was the fact that the *evening* paper, a small affair, seemed to have a vindictive feeling towards this struggling company of "philanthropists." It developed later that this feeling on the part of the evening paper was engendered by the fact that they had none of the advertising for the company. The secretary soon became "wise" to his want of tact in this matter and it was remedied and the point of view of the owner of this small paper became changed. It has not been mentioned, although such was a fact, that the morning paper had been well patronized by the company, even back to, and during the controversy with the city over its right to construct the works. Say what one will, these little matters will have weight and the older one grows, it seems the more experience he has, much of which he has paid a handsome amount for.

We will not ramble through the ups and downs experienced by these benevolent gentlemen. They were though, in a short time, a very short time, eliminated from any anxiety or charge in the affairs of the company, a "kind and gentle judge" of the United States Court having taken charge of the works in behalf of certain bondholders. A period of six years ensued under the receivership, this humble though efficient secretary still "holding on" as a manager and receiver. At the end of the six years the property was sold, the purchasers being five prominent and wealthy citizens. The demand for "caterpillar soup" had increased to such an extent that the new company had to go to expensive additions of machinery in order to keep up the supply. This brings us to the early part of the year 1880.

Chapter IV

About the years 1882 to 1884 there began to be observed quite a change in the appearance of many of the male inhabitants of the city. This change being especially noticeable in the region of the stomach, the same, in many cases, showing an inclination to protrude in quite an extraordinary manner. Men appeared to get about in quite a loggy way, seemed to find it difficult to mount to even the steps of a streetcar, some who had ridden horseback for years found it necessary to purchase low phaetons. A man would hail a streetcar and seem to have difficulty in keeping himself

from falling forward after having attained the platform. Finally, a prominent gentleman having fallen forward from a car was taken to a hospital, an examination developed the astonishing fact that his stomach was two thirds full of a concrete matter; this heavy weight was what had overbalanced him, causing his fall, and alas! his early demise and separation from his worldly goods. A drawing having been made of his stomach showing the unnatural formation, was blueprinted, copies being distributed among the city officials, but the matter seemed to have been kept from the newspapers.

During an official visit paid to the city engineer in his office the manager of the Water Company was shown by him a copy of this blueprint and it was explained to him how the city physician and another had made an official examination and the conclusion at which they had arrived; i.e., this condition was due to the subject having drank for years water furnished by the Water Company. Here was matter for serious reflection. The engineer loaned the manager the blueprint and he repaired to his home, not to rest but to *think* what could be done in this terrible condition of affairs. He suddenly remembered a visit he had made a few days previous to witness the opening of a new Ice Factory, the same having obtained a fine supply of water, clear and cool, by boring an Artesian well. The Ice Company had been using this water for some weeks. Among other things the manager of the Ice Company said was: "This water is fine for boilers; it has cleaned the scale from all our boilers, also the rust from the inside of our old water pipes, through which you know your company has supplied us up to the present time."

The Water Company manager was much interested in the subject at that time and now it occurred to him he had discovered a solution of his most difficult problem. The following day a directors' meeting was called and all this information given to the board, each member examining with especial interest the blueprint. As one observed the very great attention paid by them to this blueprint, which, being placed on the table the gentlemen had to bend over to examine, one noticed at a glance the formation of the frontal portion of the anatomy of each, and was surprised at the prominence exhibited in every case. No wonder the board were interested in the "subject matter" and listened with close attention to a plan which would immediately, if carried out, overcome all difficulties if successful in cleaning the cement from the stomachs of the people.

Immediate action was taken by that board; financial arrangements authorized to carry out plans and orders issued that work be started as soon as practicable.

In a short time, considering the extensive alterations to be made, which involved an expenditure of over a million dollars, a fine, clear, cool water was being delivered through the pipes of this benevolent corporation and from thence in copious amounts into the stomachs of the thirsty people. The "cleaning out" properties of this new supply very soon developed. A leak would be discovered over a cast iron main, same being uncovered it was found a honeycombed casting had for years been concealed by the strong cement in the former water supply. This new water cleaned out everything. Investigation also developed that a 6-inch pipe had, in former times, been reduced to a four, a four to a three, etc. This new water changed these conditions in quite a short time. Many wrought iron connections had to be replaced by galvanized iron or lead. But the happy effect that one began to see in the active movement of our men, the loggy attitude of former days rapidly disappeared.

Having followed the company through all the ramifications, having labored under two administrations of officials, and believing that they had now arrived at a final solution of this vexing matter, the manager,—after a service of some twenty years,—severed his connection with the company and incidentally with the people of the old Bluff City. Always when it has been his good fortune to visit the old place he has been warmly welcomed and also made to realize that the "old medicine" still holds its claim in a mild degree for most of those with whom he came in contact. The fine physical appearance of nearly all of them,—not removed to Elmwood,—he was glad to find, gave him assurance that his last efforts along the lines of carrying out the wishes of the most humane Board of Directors, had been successful.

QUESTION BOX

Question No. 1. Have you had any experience with mechanical cleaning of water mains?

Mr. R. L. Peeler: Yes, have used the "go-devil," such as used by the Standard Oil Company in their eastern pipe lines. This apparatus is made at Erie, Pennsylvania. Was used in the transmission line to town.

Mr. W. L. Cameron: Have not used mechanical cleaners; at Memphis when the artesian water was turned in it cut out all of the old deposit made by the river water and thoroughly cleaned the mains.

Mr. C. R. Knowles: We have in use 11,500 feet of 8 inch and 5300 feet of 4 inch cast iron main, both of which were cleaned by mechanical means about three years ago.

Mr. R. O. Wynn-Roberts: Had experience with mechanical cleaning of water mains at Carnarvon, Wales, and Oswestry, England. At this latter place by this means was able to increase the delivering capacity by about 42 per cent. This rendered it unnecessary to lay new mains. Such mains after having been once cleaned should be scraped at least twice a year. Hatch boxes were inserted at convenient points and enclosed in a brick chamber so that the frequent scraping was a simple matter.

Mr. Dexter Brackett: The experience at Boston, Massachusetts, in 1886 and 1887 in cleaning fifteen miles of 6 inch and 12 inch pipes might be of interest at this time. This was described in a paper read before the New England Water Works Association, which is of sufficient interest to reproduce here. It appeared as a discussion on a paper on the subject of cleaning water mains, presented by Mr. Gilbert Murdock. The extract is from the *Journal of the New England Water Works Association*, Volume 13, pages 341–344.

"In connection with Mr. Murdock's very interesting and instructive paper, a brief description of similar work done on the Boston Water Works in 1886 and 1887 may be of interest.

"The pipes laid in Boston from 1848 to 1868 were uncoated, and the interior surface of the pipes is covered with a coating of tubercles from $\frac{3}{8}$ inch to $1\frac{1}{4}$ inch in thickness. This coating, as proved by Mr. Murdock's statistics, very seriously affects the delivering capacity of the pipes, and, in the case of the smaller sizes, renders them practically useless for fire supply.

"The pipes cleaned in Boston were not the supply mains, but the distributing pipes in the streets, the sizes cleaned being 6 inches and 12 inches in diameter. In cleaning these pipes, the conditions were somewhat different from those of Mr. Murdock, whose work was done on a pipe of a larger size, where there were probably few, if any, service pipe connections. As many of the service stopcocks project into the pipes from $\frac{1}{2}$ inch to $\frac{3}{4}$ inch, it was necessary to have the scraper arranged so as to pass by such obstructions, and, at the same time, remove the coating of tubercles. The machine, which was very successfully used, consisted of a flexible central shaft, about $3\frac{1}{2}$ feet in length, composed of coiled steel springs connecting small castings, to which were hinged two sets of steel scrapers, arranged radially around the shaft about 12 inches apart. The scrapers were kept against the sides of the pipe by coiled springs which permitted them to turn back so as to pass taps or other obstacles. Back of the scrapers were two rubber pistons placed about two feet apart, so as to insure a pressure on the machine when passing branches. The scraper was operated in a manner very similar to that used by Mr. Murdock, except that no hatch boxes were placed in the mains. A section was cut out of the pipe long enough to receive the scraper, which was then inserted, and the joints made with lead in the ordinary manner, except that clamp sleeves were used so that the section could be again easily removed and the scraper inserted if desired. A similar piece was cut from the pipe at the other end of the main to be cleaned, and the scraper was forced through the pipe by the ordinary water pressure, which varied from 30 to 45 pounds.

"As occupants of buildings on the line of the pipes were without water while the work of cleaning was in progress, and, as it was not thought advisable to pass the scraper through valves, the pipes were cleaned in lengths averaging 1000 feet. The scraper generally passed through this distance in from three to four minutes, or about

as fast as a man would walk. In a few instances the scraper was stopped by obstructions in the pipe, the one causing the most trouble being lead which had run into the pipe at a joint. The water issuing from the open end of the pipe was the color of ink for from five to ten minutes after the scraper had passed through, and it was permitted to run until it became clear, after which the section of the pipe was replaced and the valves opened. Some difficulty was experienced from the stopping of the service pipes and house plumbing by rust forced into the pipes by the pressure of the water following the scraper, but this difficulty could be generally overcome by applying a force pump to the house plumbing and forcing the obstructions back into the main.

"By this method the tubercles were removed from 58,000 feet of 6 inch pipe at a cost of 14 cents per foot, and from 20,300 feet of 12 inch pipe at a cost of 20.6 cents per foot. These prices include 5 cents per foot royalty paid for the right to use the scraper.

"As was the case at St. John, a great improvement was made in the delivering capacity of the pipes by the removal of the coating of tubercles. Experiments were made to determine the friction in the pipes both before and after cleaning under different rates of discharge. The discharge was measured by means of a Deacon meter, and the friction head from readings of Bourdon gauges attached to the fire hydrants. Very great accuracy was not expected in these experiments, but they show very well the great loss in discharging capacity, caused by the coating of tubercles and the gain from cleaning. It will be noticed that the discharge of the 6-inch tuberculated pipes was from 25 per cent to 35 per cent of the quantity which a clean coated pipe might be expected to deliver under the same head, and that the discharging capacity of the pipe was more than doubled by the removal of the tubercles.

Tuberculated Pipe, 38 years old—Length, 525 Feet; Original Diameter, 6 Inches.

OBSERVED HEAD. FT. PER 1000	VELOCITY FT. PER SECOND	OBSERVED DISCHARGE GALLONS	VALUE OF C IN FORMULA $v = c\sqrt{r.i.}$	CALCULATED DISCHARGE OF CLEAN PIPE UNDER SAME H'D DARCY'S FORMULA
1.30	0.38	33.3	29.5	120
2.50	0.57	50.0	32.2	165
6.90	0.95	83.3	32.3	275
14.40	1.13	100.0	27.1	395
19.20	1.32	116.6	27.1	455
25.40	1.51	133.3	26.8	525
33.80	1.70	150.0	26.1	600

Same Pipe, After Cleaning. Length, 525 Feet; Original Diameter, 6 Inches.

OBSERVED HEAD. FT. PER 1000	VELOCITY FT. PER SECOND	OBSERVED DISCHARGE GALLONS PER MINUTE	VALUE OF C IN FORMULA $v = \sqrt{r.i.}$	CALCULATED DISCHARGE OF CLEAN PIPE UNDER SAME H'D DARCY'S FORMULA
2.70	0.76	66.6	41.5	170
1.50	0.95	83.3	68.8	125
1.50	1.13	100.0	82.5	125
3.80	1.51	133.3	69.4	205
4.20	1.70	150.0	74.2	215
6.50	2.08	183.3	73.1	265
9.40	2.46	216.6	71.8	320

Mr. J. A. Hiller: The Cincinnati Water Department has had about 22½ miles of mains cleaned during the past six years. These mains range in size from 6 inch to 20 inch in diameter. Many of these mains were found half filled with a deposit of mud and badly encrusted.

Mr. Leonard Bauer: We cleaned about eight miles of mains in 1912 with very good results, increasing the flow from 60 to 75 per cent.

Question No. 2. If you have had experience with cleaning mains mechanically, has it been satisfactory and to what extent did it increase the capacity of the pipes cleaned; did it obviate or delay the necessity of laying new mains?

Mr. A. W. Ellson Fawkes: At first it appeared satisfactory, and discharging capacity of mains was equal to new pipes, but the inner surface of the pipes corroded again quickly, owing to the coating having been badly damaged by the cleaning process.

Mr. R. L. Peeler: Very satisfactory. The idea is to commence when the pipe is laid and clean it out every ninety days. A force pump is used to carry the "go-devil" through the main.

Mr. C. R. Knowles: The cleaning of these mains was satisfactory, and resulted in reducing the pressure maintained on 8-inch main from 140 pounds delivering 415 gallons per minute, to 49 pounds delivering 407 gallons per minute, and at a pressure of 81 pounds delivered 600 gallons per minute, the gallons delivered measured by meter.

On the 4-inch line we had no means of measuring the water delivered, but, by running the pump at twenty strokes before cleaning, maintained 125 pounds pressure; after cleaning, by running pump at same speed, 65 pounds pressure was maintained on line. The cleaning of these mains eliminated the necessity of laying new mains, for the time being, at least.

Mr. J. A. Hiller: The cleaning has been very satisfactory. A test was made on a short length of 4-inch main which showed an increased carrying capacity of 125 per cent. The earlier contracts required pitometer gaugings after cleaning and showed flows in cleaned mains equal to the flow calculated by the Hazen-Williams formulae with $C = 100$. Since 1908 no testing has been required, the quantity of material removed has indicated to the writer that great good was being accomplished.

Question No. 3. Have you observed the effect of mechanical cleaning on the pipes and estimated the frequency with which they will have to be recleaned? That is, will tuberculation form more rapidly on cleaned pipes than on new or uncleaned old pipes?

Mr. A. W. Ellson Fawkes: Yes. About one and a half to two years, according to the character of the water. Tuberculation will form much quicker on mains that have been cleaned. If you start cleaning mains you must reclean them at intervals.

Mr. R. L. Peeler: To keep pipes to full capacity they will have to be recleaned every ninety days. Can see no difference between cleaned and not cleaned pipes so far as deterioration is concerned.

Mr. W. L. Cameron: Am of the opinion that any process of cleaning, other than by water that will cut out the sediment, will leave something to which new matter will adhere.

Mr. C. R. Knowles: The frequency with which the mains will have to be cleaned will depend largely upon the character of water. In this particular instance, tuberculation seems to form more rapidly than before mains were cleaned. The mains have been laid for a period of twelve years and were in service nine years before cleaning was necessary, while from their present condition it is evident that they will have to be recleaned within the next two or three years, or new mains laid. However, the cleaning has proved a profitable investment, as a saving of $600 to $700 per annum in fuel alone has been effected, aside from the increased capacity of the pipe.

Mr. J. A. Hiller: Pipes examined two years after cleaning are still in good condition. We have no further trouble with deposit since filtration plant is in use.

Question No. 4. In cleaning pipes have you closed the opening permanently or installed hatch boxes or other devices in manholes, with a view to future cleaning without tearing up streets and cutting pipes?

Mr. R. L. Peeler: In the transmission line we have a "Y" with gate to enter the "go-devil" and take the scale and instrument out at the end of the pipe line. Doubt if this would be good practice in distribution mains on account of the scale filling up the smaller pipes.

Mr. A. W. Ellson Fawkes: Hatch boxes are good on small mains. Above 10 inch diameter insert double spigot pipe and connect to pipe line with two clamp collars. The double spigot pipe can be removed when required to insert a cleaning device.

Mr. C. R. Knowles: The openings made at the time cleaning was done have been closed permanently, but where frequent clean-

ing is necessary, there is no doubt but what a hatch box, or other service for future cleaning, should be left at openings, with a view of avoiding tearing up of streets and cutting pipes.

MR. J. A. HILLER: No hatch boxes have been used; the mains are permanently closed.

QUESTION No. 5. Have you adopted in your office the standard system of accounts adopted by this association, or do you know of other water works or any public service commissions that have adopted it?

MR. R. L. PEELER: We have adopted the American Water Works Association standard system.

MR. CHARLES L. BOWKER: Have not adopted the system. On July 1st next the Public Utilities Commission of Maine take office, and the act creating the commission provides for a uniform system of accounts.

MR. H. P. BOHMAN: The Railroad Commission of Wisconsin prescribes the form of all books, accounts, papers and records to be kept by all Public Utilities in Wisconsin. The system installed in Milwaukee is somewhat similar to the standard system adopted by this association.

QUESTION No. 6. If you have used the accounting system have you found it satisfactory or an improvement over old methods?

MR. R. L. PEELER: It is very satisfactory and a great improvement; but it was discarded when the state of California Railroad Commission installed a system of their own, a system more elaborate and more in detail.

MR. C. R. KNOWLES: From what I know of this accounting system, it is my opinion that it is an improvement over former methods, which were principally a lack of system.

Mr. R. U. Sherman: We have adopted the general plan of accounts as adopted by the association, not, however, carrying it out to the full detail. We consider it an improvement in itself, as well as of value to all others, making future comparisons easier and more reliable.

Mr. Henry T. Boyden: In Ohio we have a State Bureau of Accounting and Examiners whose form of accounting we have to follow and which appears to work well.

Mr. Dow R. Gwinn: We have adopted the uniform system at our office. Some have objected to this system; they thought Mr. Wehr had made it too cumbersome. It does make a rather voluminous report which would have a tendency to scare a man who was running a small plant when he looked at it. He would be liable to go up in the air at first, saying, "I cannot do anything with that;" but the system is arranged in such a way that the smallest plant in the country, if it only pumps 100,000 gallons a day, can utilize that system. You do not need to use it all. It is large enough and comprehensive enough for the largest city in the United States, but it can also be adapted for the smallest plant in operation. So suggest that you do not get frightened when you look at the pamphlet which has been prepared by Mr. Wehr, but make a study of it and you will find out that it has a great many valuable features to it. Isn't that right, Mr. Ackerman?

Mr. J. Walter Ackerman: Dr. Powers, statistician of the Census Bureau, is very anxious and willing to coöperate with anybody who has any trouble and does not understand anything about it. He will set you right; or if any question comes up not fully covered by the present schedule, Mr. Powers and Mr. Wehr will thrash it out and give you some definite answer, so that there may be uniformity in it.

Mr. A. A. Reimer: The State Board of Public Utilities Commissioners of New Jersey ordered a certain form of accounts to be used, the order to take effect January 1, 1913. The final forms were based quite largely on the American Water Works standard. Some of us who knew the value of the association form worked in favor of the whole thing; but this did not strike the Senate Committee in charge of the new system of accounts as being advisable, much to

our regret. However, the form, as finally adopted and ordered put in use by every public water works company or department in the state, is based on the American Water Works Association form, and the principal headings all the way through are identical with that standard, so that in looking up the New Jersey report hereafter you will be able to get a strict comparison between any New Jersey company or department and any other company or department that reports on American Water Works Association forms.

Just as a matter of interest the speaker brought with him a "Blue Book" of the state as it is called. This is an annual report form of the Board of Public Utility Commissioners of the State of New Jersey for the year ending December 31, 1912. In looking through it you will find that the main headings show up all the way through the same as our standard. So far as the cost of changing over from your present system to the standard uniform system is concerned, you need not be alarmed. If you have a small company it will cost you a small amount. If you have a large company it will not cost you a large amount. We have a medium sized department, serving 40,000 people, and the total cost of the change from our old system to the new was about $110. So you see it is not a very expensive change. For a small company it would probably not go more than $25 to $50.

QUESTION NO. 7. With water meters owned by the consumers what legal rights or rules have you for testing and compelling repairs, when needed, to such meters?

MR. CHARLES L. BOWKER: Legality has not been questioned; consumers have never objected to the testing of their meters. If we wanted to test a meter we should do so and test the matter out afterwards.

MR. A. E. CROLL: We have privilege under our franchise to test and charge repairs to owners.

MR. F. C. AMSBARY: We set water meters and charge consumers cost of them. We keep them in repair free of cost to consumer, except when new parts are needed, which are charged to the owner of the meter. Have never had any objection to this rule.

Mr. Emmett MacDonald: A city ordinance gives us all necessary rights in the matter.

Los Angeles, California, Water Department: We have the right to protect the city from loss by reason of defective meters.

Mr. Robert Spurr Weston: Rule that meters owned by consumers shall be tested and repaired when necessary by the company at the expense of the owner.

Mr. H. P. Bohman: Under our city charter the Commissioner of Public Works has power to make rules and regulations for the distribution and supplying of water for use or consumption. Under the rules the consumer is obliged to maintain the meter.

Mr. C. R. Knowles: A consumer is subject to the rules of the water department or company with whom he is dealing.

Mr. Thomas E. Irwin: The legal right which we operate under is the Penal Code of New York State in reference to devices for measuring water. Where the meter is damaged by frost or misuse, we require the owner of the meter to make the necessary repairs or we make the repairs and charge them to the owner.

Mr. Henry T. Boyden: The legal right to turn off the water until such repairs and changes are made, as water department orders.

Mr. J. A. Hiller: In Cincinnati meters are installed by the water consumer, the department tests meters for accuracy before installation and reserves the right to remove same from premises for inspection and test. Should the meter be found in need of repairs the owner is notified to have same repaired and returned for test within 30 days, failure to do so being sufficient cause for shutting off of water.

Mr. Edward H. Grow: The rules and regulations at Washington, D. C., governing this are as follows:

No water from the mains shall be introduced or used on premises supplied through water meters excepting that which passes through the meter.

Water meters and appurtenances shall not be removed, repaired, or in any manner tampered with, excepting upon a permit from the Water Department; and whenever a meter is removed for any cause, the Commissioners may require another to be put in its place.

The Commissioners may at any time require any meter to be removed and sent to the Storekeeper's Office, Water Department, for inspection and test. They may require that any meter shall be repaired, and, if in their judgment, a meter is deemed unfit for further service, they may require it to be replaced with a new meter.

Mr. M. L. Worrell: At Rome, Georgïa, the city owns the meters and makes repairs. They do not allow anybody to meddle with the meter under any circumstances. That is disposed of under a city ordinance.

Mr. Earl W. Kelly: In Duluth the consumer buys and owns the meters. All repairs are made by the department at the consumer's expense.

Mr. A. A. Reimer: Speaking on Question No. 7 the speaker would like to suggest that at next year's convention we might have an argument, or invite some kind of a mixup on the question of the ownership of meters. The speaker feels very strongly on the point of the ownership being by the company or the department. He does not see why we should be in any different position in that matter from owning our pipes or our hydrants. The meters are just as much a part of our system as the pumps that we pump with or the fire hydrants that we fight fires with and other parts that no one ever thinks of selling to private parties; and this association should be on record as opposing the ownership of water meters by consumers.

Mr. E. E. Davis: In our city nearly all meters are owned by the city. If a meter that belongs to a consumer gets out of order we notify the consumer that the meter is out of order, and if he declines to repair it, we have it done and it is charged up to him. All meters larger than one inch belong to the consumers.

Question No. 8. How can check valves on private fire services be tested?

Mr. R. J. Smith: By tapping main between check and gate valve and using a pressure gage.

Mr. Charles L. Bowker: Put a gate valve on each side of the check valve and with a three quarter or half-inch connection test out with a force pump.

Mr. C. R. Henderson: Place gate valves in fire line next to main, then check valve with test opening between check and gate and a by-pass around both. Close gate, open by-pass and test.

Mr. F. W. Frank: Start the pumps and put a pressure on exceeding the city pressure. Put gages on at various points to show if the pumps increase the pressure outside of the check valves.

Mr. H. P. Bohman: By comparing pressure tests taken on both sides of check valves, with inlet valve closed. To avoid contaminating domestic supply through defective check valve we close and seal discharge valve of fire pump, which seal can only be broken in case of fire.

Mr. William Perry: A gate valve should be placed behind the check and between the two a piece of pipe with a cover that could be removed, which would show at once if any leakage took place. Check valves should be made with a rubber washer or face; such check valves will never leak, have had them in for years and not a drop of leakage from them.

Mr. H. O. Lacount: The kind of test which is necessary will of course depend upon the accuracy desired, and this in turn will be governed by the amount of leakage which is permissible. Whether a certain leakage is objectionable or not will depend on the viewpoint from which the question is considered.

From the strictly fire standpoint, a small leakage would ordinarily not be important except in the case where the second supply for the fire system is an elevated tank. If the tank pressure is more than that from the city, leakage of the check valve would mean a waste of water and a lowering of the pressure from the tank. If the city pressure is the higher the leakage of the check would for the same reason be important in case of reduced city pressure on account of heavy draught in the public mains due to breakage or an unusually

large demand for water. With such a limited water supply as a gravity tank, any waste of water is undesirable.

Probably the best way to test a check valve under these conditions, if suitable pumping arrangements can be provided, would be to raise the pressure on the yard side of the fire service check valve to some point in excess of the city and tank pressures and note the strokes of the pump per minute necessary to maintain that pressure. Then shut off the tank and again note the strokes per minute of the pump necessary to keep the pressure at the same point as before. If it is necessary to pump less water with the gate valve shut than with it open, it would be evident that the check valve in the tank connection was not tight, but if practically the same amount of pumping is necessary in both cases, this check valve could be considered substantially tight.

Having determined that the tank check is tight, the gate valve in this connection should be immediately opened and the same test applied to the check valve in the fire service connection from the city mains. The object of testing these two checks separately is to prevent shutting off the entire fire supply at the same time, and with the procedure above outlined, the supply from either the tank or city system would be available at all times.

The above assumes of course that there is no draught from the fire system for manufacturing or other purposes.

Extreme caution should be used in making these tests, for while they are in progress, the fire protection would be somewhat crippled, and a competent man should be kept stationed at the closed valve ready to turn it on at a minute's notice of fire in the property.

When the secondary supply is from a fire pump, leakage of the fire service check valve is objectionable from the fire protection standpoint only when it amounts to enough to prevent the maintenance of good fire pressure from the pump or materially reduces the amount of the pump water available for fire fighting. Otherwise a small leak would not be serious and a leak that would be objectionable could usually be determined by using the fire pump and testing as already described, closing the gate valve in the fire service connection temporarily.

However, from the standpoint of the purity of the public water, a small leak might be objectionable, if the secondary fire supply was a pump draughting from an impure source. For such conditions, an arrangement for protecting the public water supply has been worked out by the Inspection Department of the Associated Factory

Mutual Fire Insurance Companies, using two check valves in series in the fire service connection, these valves being of special design and construction, and equipped with test connections for the convenient and systematic testing of the valves from time to time. The accompanying cut shows this device and method of testing. As noted in the cut, the specifications under which these valves are made require the internal parts to be of composition, the clapper to be faced with medium hard rubber, the moving parts to have liberal clearance in all positions; and to facilitate the work of inspection of these valves which should be done occasionally, the covers and cover flanges are made with slotted bolt holes and the opening at the bonnet is of sufficient size to permit the clapper to be swung out of the body, giving ready access to the rubber facing and the valve seat. There are already three manufacturers prepared to furnish these special check valves, namely, the Chapman Valve Manufacturing Company, Indian Orchard, Massachusetts; the General Fire Extinguisher Company, Providence, Rhode Island, and the Ludlow Valve Manufacturing Company, Troy, New York.

An intelligent and systematic test and inspection of this double check device, as already referred to, is essential for the desired results, and the frequency with which these tests should be made will depend somewhat upon the conditions, but usually a test once in two months or possibly in some cases once a month, has thus far been found sufficient for the desired assurance that the valves were in good working condition. In addition to the regular tests, it would be advisable to occasionally, say once in six months or once a year, thoroughly inspect the valves by removing the covers and thoroughly cleaning the valves inside.

This double check arrangement has already been installed on a number of fireservice connections in several cities and, after three or four years of field service, not a single case has yet been reported where both checks, in the same connection, have been found leaking at the same time, in other words, the arrangement as a whole has thus far been found efficient, showing a very satisfactory record and giving evidence of the reliability of the arrangement under practical conditions.

Mr. C. R. Knowles: The best method of testing check valves on private fire services is to install the check valve in a box or manhole, with a gate valve behind the check, and a telltale valve between the gate and check valves.

NORMAL CONDITION OF VALVES.

OPEN.

Ind. Post Gates A-G.

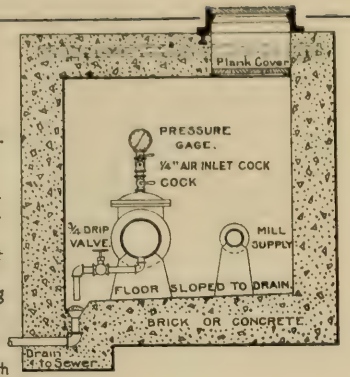
SHUT.

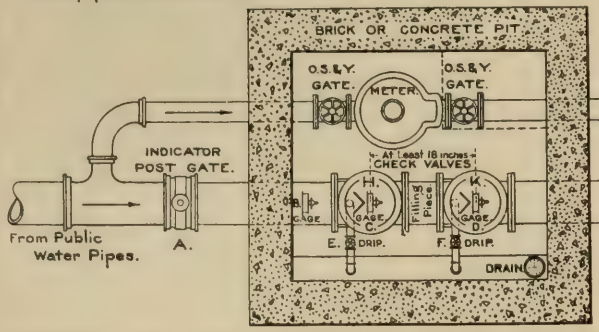
Cocks B-C-D.

Drip Valves E-F.

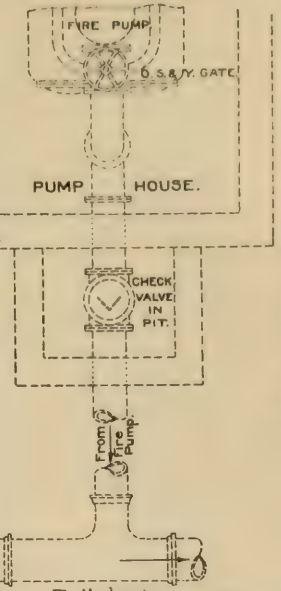
Once in six months inspect check valves and thoroughly clean whole interior, removing discs if necessary.

To facilitate removing check valve covers, pack with manilla paper and machine oil.





The specifications under which these special check valves are made require the seat ring, disc, holding ring and screws, disc stud, arm, hinge pin, and bushings to be of bronze; disc to be faced with medium hard rubber and liberal clearances left around clapper and arm in all positions.



METHOD OF TESTING.

Close gate A and open drip E and air cock B.

If pressure holds at gage C but flow continues at E, gate A or check valve H leaks. To determine which is leaking, open drip F and if gage C falls to zero and if flow from E does not decrease, gate A is leaking and valve H is tight.

Open air cock C and if flow from F ceases, valve K is tight.

For testing under higher pressures, close gate at G and use a hand force pump attached at F to test tightness of H. Open G and start fire pump to test K

CAUTION immediately at close of test see that gates A and G are open.

FIRE SERVICE CONNECTION

USING TWO CHECK VALVES

Mr. W. R. Gelston: Arrange private fire services with a gate valve as near the main in the street as possible. Locate the check valve close enough to the gate valve so that you can enclose both of them within one valve well which is closed with a manhole plate. Insert a corporation cock in the pipe between the two valves and it is a very easy matter for one man to get into the well and close the gate valve. If the check valve is working properly, the corporation cock can safely be opened.

Mr. Henry T. Boyden: It is our practice to place a shutoff valve near the main; a tap between the shutoff valve and the check valve should quickly determine if the check valve is tight.

Question No. 9. What has your experience been with various materials for services? Information wanted as to the various materials used, such as lead, galvanized iron, galvanized steel, lead or tin lined, cast iron, etc.

Mr. R. J. Smith: Galvanized iron gives better results than lead pipe at Perth, Ontario. Lead pipe crystallizes and pits full of small holes in some soils here, in from four to six years.

Mr. R. L. Peeler: Use galvanized iron and it gives fairly good service.

Mr. A. W. Ellson Fawkes: It depends entirely on the character of the water supplied. Good quality of galvanized iron service pipes are satisfactory in Calgary, Alberta.

Mr. Charles L. Bowker: Have used only galvanized wrought iron services; they last an average of eighteen years.

Mr. Charles R. Henderson: The speaker believes lead to be the best, especially when laid under pavements. Also, advise the use of lead flange connections instead of wiped joints.

Mr. F. W. Frank: Have found lead pipe most satisfactory for services. With us—Brantford, Ontario—iron or steel, either plain or galvanized, rusts out in six to ten years.

Mr. A. E. Croll: We use only galvanized iron, which lasts about twenty years. We are now replacing galvanized services with new ones of the same material.

Mr. F. C. Amsbary: We use genuine wrought iron, galvanized. We have occasional leaks and have to renew some services. Consider the average life of galvanized iron about twenty years.

Mr. T. J. Bird: Lead stands all right in the soil at Lake Charles, Louisiana. Black iron lasts two to four years; galvanized iron or steel five to eight years.

Mr. Emmett MacDonald: Have best success with galvanized iron. Lead corrodes and clogs with our water.

Mr. Lewis M. Bancroft: We use galvanized iron and lead lined iron pipe.

Mr. Robert Spurr Weston: Galvanized iron has given the best service with surface waters. Cement lined with ground water.

Mr. H. P. Bohn: We use extra strong lead up to 1 1-4 inch diameter. Above that size cast iron hub and spigot pipe may be used.

Mr. Scotland G. Highland: Unquestionably lead services give most satisfactory results. We recently removed a lead service pipe after twenty years of continuous use and found no evidence of corrosion, while galvanized iron seldom gives proper service after twenty years.

Mr. William Perry: Have found lead pipe satisfactory in almost every detail. Tin lined iron pipe is good, but the cost is against its use.

Mr. Henry T. Boyden: Our only experience has been with wrought iron and lead pipe. Lead pipe is satisfactory unless it gets strong and direct electrolytic action.

Mr. C. R. Knowles: Have obtained very good results from galvanized iron and tin lined pipe, coated with asphaltum and

wrapped with burlap for small service lines—3 inch and smaller. Favor using cast iron for service pipes larger than 3 inch.

Mr. R. O. Wynne-Roberts: Found galvanized iron water-service, used where the water is soft, to corrode quickly; to use lead pipe under such circumstances was somewhat risky, as the lead was liable to be acted upon by soft water, tin lined lead pipes are expensive, and certain galvanic action is stated to take place between the metals. With certain moorland waters the slimy deposits effectively coat the lead pipe and prevent plumbism, but where no such coating occurs, then the best quality of galvanized iron pipes are the best for such work. With hard water both lead and galvanized iron pipe answer well.

Mr. Thomas E. Irwin: Regret to state that our experience with various materials is somewhat limited. Our company adopted a rule when first in operation that nothing but galvanized iron should be used for services and it is only recently that we have allowed the use of any other material. Our experience with galvanized iron is that it has a tendency to corrode the pipe to such an extent that at the end of ten or fifteen years it is necessary to replace same.

Mr. W. R. Gelston: Our experience with so called galvanized iron has been such that we discontinued the use of it something over one year ago and are now using extra strong lead pipe on all services up to one inch. We use cast iron pipe for services larger than one inch.

Mr. J. A. Hiller: Cincinnati requires lead or brass (iron-pipe sizes) for all branches less than 2 inches in size, cast iron is required for all larger sizes. Lead services in use for thirty years in good condition.

Question No. 10. What has been your experience with lead or tin lined iron pipe for services? How does it compare in cost with lead?

Mr. Lewis M. Bancroft: Have used lead lined pipe and have had no trouble with it.

MR. W. U. SHERMAN: We have recently used lead lined pipe for services from one inch to two inches in diameter in the section where our pressure is high, that is, over eighty pounds. We think it is less apt to give out under such pressures than lead.

MR. EARL W. KELLY: Would like to know if any of you have had any experience with corrosion of lead services where apparently, electrolysis could not be blamed for the trouble? We have had that in some localities in Duluth. The lead becomes pitted on the outside quite deeply, in fact finally amounting to perforation; and the material in the service itself seems to lose all its life. This has happened in sandy soil and in the red clay which is more common there.

SECRETARY DIVEN: Are you sure it is not electrolysis?

MR. EARL W. KELLY: It is in a locality that is removed from any current.

PRESIDENT GWINN: Electricity "moves in a mysterious way its wonders to perform."

MR. EARL W. KELLY: We have made a survey of our system of the comparative potential of the mains to the rails; and the districts referred to were all along ranges reaching out into the country, with no returns toward the main part of the city.

PRESIDENT GWINN: Go anywhere near the lake?

MR. EARL W. KELLY: In one case it did.

MR. A. A. REIMER: Another thing you want to notice is its proximity to telephone or electric light conduits.

MR. EARL W. KELLY: It is away from the central portion of the city where there is not any underground electric work.

MR. A. A. REIMER: Electric currents from whatever source play havoc with services.

MR. E. E. DAVIS: Have any of you ever seen lead pipe pitted by electricity on the bottom? It is always on the side, or top. The

speaker recalls sometime ago when his foreman and the engineer of the railway company each had a piece of pipe and kept turning it over. The foreman said, "Come here and decide this question for us. Is this electrolysis?" The speaker looked at it and said, "No, it is lime action." They said, "How do you know?" The speaker replied, "Look at the piece of pipe and you will find the pitting is all on the top and side." Red clay that has white streaks in it will eat the pipe all round. You will never see a piece of pipe destroyed that way in gray soil or sand.

QUESTION No. 11. Who should own the service from the main to the curb line?

MR. R. J. SMITH: The consumer owns it at Perth, Ontario, and it works out all right.

MR. R. L. PEELER: The service to the curb line should be owned by the water company.

MR. A. W. ELLSON FAWKES: The water service to the curb line should be owned by the water department.

MR. CHARLES L. BOWKER: The water company or city water department should own the service to the curb. In Brunswick, Maine, they are paid for by the consumer and repairs made at the expense of the district, except entire renewals.

MR. C. R. HENDERSON: It is a question of policy governed by circumstances. If owned by water department, earnings must provide for interest, repairs and depreciation. The plan of consumers owning the services works best in most cases.

MR. F. W. FRANK: The corporation should in all cases own the services to the curb line.

MR. T. J. BIRD: The consumer is required to put in the service and keep it in repair at Lake Charles, Louisiana. But the writer has some doubts about this being the best plan.

Mr. J. B. Chessington: If a municipal plant, the city should own the service; also, if the charter of a private company provides for purchase by the municipality the service should be owned by the water company.

Mr. H. P. Bohman: In Milwaukee service pipes are owned and must be maintained by property owner. There are many good reasons why services from the main to the curb should be owned by the city.

Mr. W. E. Hazeltine: We believe that the consumer should own his own service.

Mr. W. L. Cameron: The water department should own the service to the curb. The first installation can then be first class, and will always be under the control of the water department, which can regulate the pavement, etc. Water rates should be based on the ownership and upkeep of the services.

Mr. Scotland G. Highland: The municipality or the company, as the case may be. All services should be laid at a proper and uniform depth according to local climatic conditions. A charge should be made sufficient to cover the cost of communication pipes with a margin for profit to care for leaks. When the owner desires to increase the size of existing communication pipes he should be required to pay the cost of all labor and materials.

Mr. William Perry: Whoever owns the water works should be responsible for the laying and connection to the mains or street lines.

Mr. C. R. Knowles: The city or company should own the service from the main to the curb.

Mr. Thomas E. Irwin: This company has always compelled the property owner to pay the cost of installing the service from the main to the curb line. But it is a question which the writer has taken up with the company a number of times, as he believes that the service pipe from the main to the curb should belong to the company. We have inserted in our Rules and Regulations that we have control of them to the curb line.

Mr. W. R. Gelston: Our company owns the service to and including the curb cock and box and keeps that portion of the service in repair. We consider this the best practice.

Mr. J. A. Hiller: The question of ownership is rather vague. The service, whether in the street or within the property lines, should be under the control of the water department.

Question No. 12. If owned by the department or water company, should the consumer or department or company pay for installing?

Mr. R. J. Smith: The consumer pays for installing from the main to the property line at Perth, Ontario; works owned by a company.

Mr. R. L. Peeler: At Coalinga, California, the water works pays for the installation of the services.

Mr. A. W. Ellson Fawkes: At Calgary domestic services are put in free of charge; trade connections are charged for.

Mr. Charles L. Bowker: The company pays for services at Brunswick, Maine.

Mr. Newton Mitchell: The Paris, Kentucky, water company charges the consumer about half the cost of the service.

Mr. F. W. Frank: At Brantford, Canada, all ordinary size services are put in by the water works; large size services are charged the additional cost above that of the ordinary size.

Mr. A. E. Croll: The cost should be borne by the consumer. At Iron Mountain, Michigan, a flat charge is made for the tap and service to the curb line.

Mr. Robert Spurr Weston: A uniform tapping charge should be made. The cost of installing services should be borne by a water company, against which cost the tapping charge should be credited.

MR. J. A. HILLER: It makes small difference who pays directly the first cost. If the water department pays it, it must of necessity charge higher rates for water, so in the end the consumer pays for the installation.

SECRETARY: Of twenty-three replies to Question 11 eighteen say the department should own the service, and five that it should be owned by the consumer.

Eighteen replied to Question 12, ten in favor of payment for services by the consumer and eight by the company or department. This indicates that five think that, though the ownership is with the company or department, the cost should be borne by the consumer.

QUESTION No. 13. If services are owned by the consumer how are leaks in them handled?

MR. F. W. FRANK: At Brantford all leaks in the street are taken care of by the water department. Leaks on private property are taken care of by the owner; but if he neglects to make prompt repairs they are made by the department and the cost charged to the consumer.

MR. A. E. CROLL: At Iron Mountain, Michigan, we compel consumer to make repairs; if he neglects to do so we dig down to the corporation cock and shut off the supply; and charge the actual cost of this to the consumer, which must be paid before the water is turned on again.

MR. F. C. AMSBARY: We maintain and repair all service pipes at the expense of the company at Champaign, Illinois. This is provided for in the franchise; which also provides that the company receive $10 for a $\frac{3}{4}$ inch service from the main to the curb on streets where mains are laid.

MR. EMMETT MACDONALD: At Lincoln, Illinois, we find it hard to get the consumer to pay cost of repairing services in the street. The company has the exclusive right to make repairs.

Mr. Lewis M. Bancroft: At Reading, Massachusetts, leaks in services are repaired by the water works and paid for by the consumer.

Mr. H. P. Bohman: Owner is given 48 hours to repair leak. If notice is not complied with within the prescribed time the water department makes the repairs, and charges the cost of same to the property. Repairs of this nature are a lien against the property.

Mr. W. L. Cameron: A matter so difficult that the writer thinks the company or department should own the service, as proper control would be impossible otherwise.

Mr. C. R. Knowles: All leaks should be handled by the water company or department; if service is owned by consumer, he should be billed for cost of repairs.

Mr. R. U. Sherman: The owner is notified to make repairs when leaks are discovered; if after reasonable time repairs are not made the service is shut off at the main. However, we are frank to say that we find this method of repairs for services troublesome and not so efficient as we would like.

Mr. Thomas E. Irwin: At Huntington, Long Island, New York, all leaks in services to the curb are taken care of by the water company without charge to the consumer. We have tried to collect the cost of service repairs a number of times, but met with so much objection that all charges of this kind are charged to maintenance and repair account.

Mr. W. R. Gelston: Consumers are required to repair leaks on their side of the curb box; we repair leaks on street side of curb box.

Mr. J. A. Hiller: Water consumers are required to keep their service branches in repair. When leaks occur in the street the department does the necessary excavating, back filling and street restoration, for which the consumer is charged from $4 to $13.50, depending on the kind of street surface. The consumer must, in addition, secure the services of a plumber.

When leaks occur inside curb cock, consumers are given 24 hours to have them repaired. Failing to do so water is shut off.

QUESTION No. 14. When the consumer owns the service, who is responsible for repairs to and condition of the curb box?

SECRETARY: Eight of those replying require the consumer to take care of the curb boxes; five cities or companies make repairs to and are responsible for the curb boxes.

QUESTION No. 15. Have you had or do you know of any legal decisions or state legislative action concerning laying of services from main to curb?

MR. R. L. PEELER: The California Railroad Commission has recently ruled that water companies lay services to the curb line.

MR. F. C. AMSBARY: Where franchise makes no provision, have heard of court orders requiring water companies to lay services to curb at their expense.

MR. W. L. CAMERON: In Memphis, Tennessee, about 1889, the city passed an ordinance compelling the water company to put in all services to property line and to repair all leaking services.

MR. HENRY T. BOYDEN: Sections 3812 and 3812–1 of the General Code of the Laws of Ohio give city council and director of public service ample power over the laying of services to the property line.

MR. M. L. WORRELL: In Mississippi we bow in humble submission to a decree of the Supreme Court which says, in effect, that while the owner shall lay the original service at his own cost and expense the city or company shall take care of it thenceforth and forever, and when the original is consigned to the junk heap the new service shall be relaid at the cost and expense of the city or company supplying the water. In that decision it was assumed that the owner could not obtain permission of the city to repair or relay the service pipe, though the same process of reasoning seems not to apply to the original installation. Do not understand why this is the case; that it is law until the Supreme Court reverses itself is the fact that is troubling the different water departments of the State.

It is the present intention of the city of Meridian to lay all service pipes, both originals and renewals, at the expense of the water department.

President Gwinn: There have been three or four decisions recently in which the Supreme Court has decided that the company was required to furnish water up to the curb or property line.

Mr. M. L. Worrell: Further along, Question No. 12 comes under practically the same head: "If owned by the department or water company should the consumer or department or company pay for installing?" The water department expects to do that as soon as the city clerk can draft an ordinance covering it.

President Gwinn: The tendency of all the decisions, especially under the Wisconsin Commission has been to require the company or department to keep service pipes in repair; and they decided in one case in particular that the company should not be required to pay for the service pipes to the curb as a great many had already been put in, and it would be a discrimination to allow the new consumers to get service pipes without charge when the others had paid for them; but they require the company or the department to maintain them at the expense of the company or department.

Secretary Diven: Is it a fair proposition to require the company to maintain a service pipe that was put in by somebody else without any regulation by the company to prevent the putting in of poor material? It does not seem right that iron services or lead services of too light pipe, with cup joints and poor workmanship, should be put in and then make the company assume the responsibility for them. If they had been put in under the strict rules and supervision of the company there would have been some reason in it; the city itself gives to some plumber a permit to put in services and then asks the company at its expense to take care of them. That does not seem to be a fair proposition.

Mr. Frank L. Anders: Is there not a limit to the amount of work that a company can do at its own expense? It seems to the speaker that those decisions add expense to your cost of maintenance that you cannot provide against.

Mr. A. A. Reimer: It seems that this question harks back to another point and that is as to who puts in the services? And there again standard practice should require the department or the company to place the services up to the curb line, or the property line. The only reason why we should stop at the curb is that there are so many new streets where final sidewalk grade is not established; but with the conditions as they are we have got into the habit of placing our curb boxes, as we call them, at the curb. You know very well that the actual street extends to the property line in the majority of municipalities. A municipality owns up to the property line, and it has become the custom to put the curb box at the curb line because it is handy to get at; but the rule ought to be to put the service right up to the property line. In the majority of the states the property line is back of the curb line a considerable distance. The only reason why we put the curb boxes at the curb line is for convenience. You cannot answer the question until you have considered the element of who places the service, and other elements also.

President Gwinn: This may be of some interest to you; combining two compilations that were made of data on this subject, in 168 cities service pipes were paid for by the customer or property owner, or 79 per cent of the 213 cities listed. In the other 45 cities service pipes were paid for by the department or company—21 per cent. That is, 79 per cent were paid for by the property owners and 21 per cent were paid for by the city or the company. In our own home town we charge $8 for a service pipe to the curb. We put in lead services complete.

Question No. 16. Is it your practice to compel property owners to lay services from the main to the curb on streets that are to be paved or do you lay such services as part of construction work?

Mr. A. W. Ellson Fawkes: A special charge of $25 upwards is made when paved streets and sidewalks have to be broken up to lay services. They are not laid as part of the construction.

Mr. C. R. Henderson: The property owner is required by city ordinance to lay a service to the curb in advance of paving street,

the theory being that pavements are thereby less liable to be disturbed.

Mr. F. W. Frank: At Brantford, Canada, we lay such services and charge it up against the property as part of the construction on local improvement plan, and as soon as they are connected up and we get a revenue from them we refund the amount collected.

Mr. A. E. Croll: Consumer is compelled to pay for service from centre of street, including a charge of $5 for tap, which includes corporation cock, lead goose neck, curb box and curb stop.

Mr. F. C. Amsbary: We lay all water mains in parking, between side walk and curb in resident districts, and do not make connections for vacant lots before paving. We push service pipes under pavements when mains are on opposite side of street, therefore, do not disturb pavement.

Mr. Lewis M. Bancroft: In Reading, Massachusetts, such services are laid as part of construction work.

Mr. Robert Spurr Weston: Such services should be laid if the property owner pays the tapping charge.

Mr. H. P. Bohman: When a street is to be permanently improved in Milwaukee, property owners are given ten days time to extend services to curb line. After the expiration of the ten days the city lets a contract for services not put in and assesses the cost of the work to abutting property.

Mr. C. R. Knowles: In the speaker's opinion such services should rfom part of construction.

Mr. R. U. Sherman: The city of Utica, New York, requires services laid to the curb for all vacant lots on streets to be paved; and the owner pays for them.

Mr. Thomas E. Irwin: Our practice at Huntington, New York, is to require the property owner to lay services to the curb line, in streets that are to be paved, at his own expense.

Mr. W. R. Gelston: The city ordinances of Quincy, Illinois, require all street mains and services to be laid before streets are improved and hold the water company responsible for their installation. We doubt the wisdom of such ordinances so far as service pipes are concerned, because services so laid in front of vacant property are seldom in the best place when buildings are erected, and they are just as likely to leak as services that are in use.

Mr. J. A. Hiller: Within the past two years service branches have been laid to all vacant lots in Cincinnati. The work is done by the city engineering department and is included as part of the street improvement. Property owners can install the services themselves, but if they fail to do so the service is put in and made a part of the assessment.

Mr. W. F. Wilcox: The ultimate solution of whether or not the company should care for the service pipes will be largely governed by the local law and the ability of the superintendent in charge of the plant. Suppose that we had a minimum rate to the customer of $1.00 a year, and suppose that the care of the services throughout the city was 20 cents per service per annum. If a man walked into your office and gave you a dollar and you gave him back 20 cents what would he think he was getting for the 80 cents? Would it not be better, for the consumer, to charge him $1.00 and keep the service up, rather than to give him that 20 cents change, and maybe in three or four months he would have to pay a plumber $15 or $20 to care for that service.

Another question which arises is this, that in states where the consumer owns the services oftentimes friction arises between the manager of the company and the individual consumer as to when the service pipe needs repairing, and the service pipe maybe leaks, and the city inspector comes along and says, "We are going to hold you for damages if you do not stop that leak." The water company goes to the individual and says, "It is your duty to repair it." He says, "No, I do not get any water until after it passes the meter, therefore you must repair it." It has occurred to the speaker that where the law permits and it is possible to do it, it might be better for the ultimate good of the water works if the superintendent would arrange to take care of the service pipe up to the meter. The meter is the point where we measure the water and practically deliver it to the consumer.

President Gwinn: If any of you are interested in legal decisions in regard to laying service pipe up to the curb and will drop a line to the speaker to that effect he will be glad to give you a list of cases that have been tried in the last year and a half. Our legislature tried last season to pass a bill which would compel all gas, water and heating companies to lay service pipe up to the curb, which is ridiculous on the face of it, because a party may come and say, "I want a 6 inch pipe or a 4 inch." We took that matter up, and the bill was dropped in committee.

Secretary Diven: Why not give those decisions for general information, by publication in the proceedings?

Mr. Earl W. Kelly: In Duluth, the consumer pays for and owns the service. He pays for it on the basis of the distance from curb to street center. The water department installs the service, but does not make any charge for curb box or curb cock, and these remain the property of the department. Beyond the curb line, services are installed by licensed plumbers, under the inspection of the department.

Repairs to the service between curb and main are made by the department at its own expense. When renewals become necessary, however, they are billed to the service owner. All repairs beyond the curb cock are made by the consumer at his own expense.

President Gwinn: The Board of Public Works in getting bids for street paving also asks for bids for service pipes and sewer laterals to the curb; then the city engineer gives us an order to lay service pipe to the curb for each lot that is not already provided with water. We find out where they have not been put in and we lay them; if a consumer wants to pay for them he does so; if not, it goes on the assessment roll and is paid into court, and the contractor, when he receives his money, pays us. We put those in at a charge of $7 apiece.

J. Walter Ackerman: We are working under an enactment which gives the water department a separate existence under the city government. One of the provisions of that act requires that service pipe shall be put in by the department at the expense of the property owner. The question is, whether that provision is a wise one as it stands. We have to live up to it; and whenever a street

is to be paved we get the subdivision of that street and put in the service pipe for every lot, giving each owner notice of it that they may fix the location. If it is not fixed it is stated that it will be placed in the center of the lot. Our bills for this work, if not paid, become liens and are turned over to the tax collector for collection.

Mr. A. A. Reimer: The speaker feels very strongly in opposition to laying of services prior to their use. A good many places are carrying low pressure on their pipes, and the argument does not apply so forcibly there as it does in our case where we are carrying pressure from 50 pounds up to 125 pounds. In the ordinary services you have from four to five joints at least, and, therefore, there are at least four or five places where leakage is possible. Another thing, in spite of every care that you may take in getting locations for the future, you do not hold to your future locations, do not forget that. Somebody will buy two lots and later sell one and then he will want services put in for each half of the double lot; or instead of dividing it up on a basis of 50 feet some one will want to divide up on the basis of 30 or 35 feet, and then there are two or three services where formerly there was but one; or again, if several lots are thrown into one in the future the old services remain there under pressure, and the next thing there is a spring reported somewhere after the record is perhaps ten years old and the location of the old services has been practically forgotten. Some one says, "What a beautiful spring that is!" And meanwhile you are losing water out of your mains. We have had that experience.

We ought to fight against this plan of placing services before they are required for use. We refuse absolutely to do it in East Orange except in a very few rare cases. We fight against it right along.

Mr. Earl W. Kelly: The speaker would like to indorse the sentiments of the gentleman from East Orange.

In Duluth, a considerable percentage of services installed in advance of applications therefor are never used; for instance services were laid for each lot on one of the business streets, several years ago, in advance of paving. That has since become a congested business street, and not one of those services has ever been used. The present consumers desire a service of different size or in a different place from that laid at that time.

These "dead" services are more liable to freezing than are "live" services, and a few freeze-ups weaken the lead pipe so that our

pressure, which has a maximum of about 130 pounds, bursts the service. The frost acts very erratically, so we cannot cheaply guard against freezing a "dead" service. For instance, though six feet of cover is usually safe, 6 inch mains with over eight feet of cover have frozen, in Duluth.

One of these breaks necessitate four or five times the expense, in repairing pavement, that would be necessary were the service put in after the paving is done.

Mr. M. L. Worrell: Meridian is now under superintendent form of government, a slight change in title only from the commission form, and it seems to be the disposition of this administration to lay a 2 inch special service pipe just inside of the curbing and to tap this, when taps are needed for the adjacent houses, rather than run service pipes from the street main to each separate place. This should be a good solution of the lead service problem ahead of paving, with its many items of cost and trouble, with the likelihood of many service pipes never being called for. The material used should be 2 inch galvanized iron pipe and as there are fewer taps connecting it with the main line there should be less trouble "from lively springs" than has been experienced with the numerous separate service pipes heretofore run and left unused and forgotten. These 2 inch submains should, by all means, be diagrammed on the map of the distribution system.

There has been only one case in Meridian where one of the service pipes, laid ahead of the paving operations, was clandestinely used; the plumber doing that was detected and fined $25.

Mr. E. E. Davis: In our city the consumer pays the plumber for the pipe, but we put it in at the expense of the city. When it comes to paving a street we run a connection opposite each lot up to the curb. If the lot is built on we run it to the property line. If a man has a 30 foot lot we never put a connection less than $\frac{5}{8}$ inch. If he builds a house that has two apartments we branch it in at the curb, never take up the roadway. These pipes are put in by the city up to the curb line or property line as the case may be. According to an ordinance of long standing all connections are measured from the nearest corner; when a plumber comes in to sign for water for a house he pays the fee for the pipe or sends the pipe to us. When a street is laid and paved and all these connections are made

opposite every lot all the property owner pays for is the cost of the lead pipe in his service.

PRESIDENT GWINN: We have a special thread on all the curb cocks, which require a coupling furnished by the company.

MR. M. L. WORRELL: In one case at Meridian we swore out a warrant for a plumber for failing to comply with the ordinance and it cost him $25.

MR. E. E. DAVIS: If a plumber connects up with a building it costs him a penalty of $20 a day until he gets a permit; that is the law. They do not make connections without getting a permit.

MR. W. W. DE BERARD: Every one who has driven a car over an asphalt street where a beautiful pavement has been laid and then afterwards torn up to put in services knows what the result is in marring the pavement. In Chicago they try to have the connections put in before the paving is done. Another excellent practice which prevails in El Paso, Texas, is to place a block of concrete 18 inches thick in the trench after back-filling. This concrete is brought up level with or slightly above the pavement and is left in place at least thirty days before the surface patching is done. When ready for resurfacing the concrete is cut down $2\frac{1}{2}$ or 3 inches or whatever the depth of the top coat is. Patched spots are hardly visible.

MR. E. E. DAVIS: When we dig a trench into an asphalt pavement a concrete block is put in there 5 inches thick and extending over each side of the trench, forming something like a bridge. The city requires that concrete shall stay there twenty-four hours before the paving is relaid with just sufficient sand between the paving and concrete bridge to keep it from settling. You would not know it had been repaved unless somebody were to tell you. We make a bridge that just bridges the trench; it laps over each side about 5 or 6 inches.

MR. A. A. REIMER: The speaker would agree to these services being placed in advance of paving new streets even though it meant loss of water if he could see that the pavement was saved thereby; but such is not the fact. As has been brought out here, the services are lost track of; they are misplaced, and consequently you have

to rip up your pavement in order to put them in where a man wants them; or instead of a half-inch service he wants a 4 inch service or some other size, and you have to rip up your pavement.

Question No. 17: Have you made any tests of the strength of lead pipe, to ascertain the weight of various sizes to be used for different pressures?

Secretary Diven: That question was suggested by a letter asking for standards. The matter was taken up with the manufacturers to find out whether they had a standard. They said they had not.

President Gwinn: Professor Scott of Purdue University says they are prepared to make tests of different materials and will be glad to do so if it will assist us.

Mr. R. J. Thomas: The question of service pipe is something that we do not know much about. In Massachusetts where they have had all the different kinds of pipe in use for thirty or forty years they are not satisfied that lead pipe is much better than common iron pipe. In the older cities they have found that lead pipes fill up and are very hard to keep clean, because they are not laid straight. In most of the Massachusetts cities where they have had water works for forty years or more they have come to the conclusion that it is cheaper today to put in plain wrought iron pipe, and not bother with lead pipe. They have not the confidence in lead pipe that they had ten or twenty years ago. And they do not put in $\frac{5}{8}$ inch pipe any more; they are laying mostly 1 inch iron pipe for the smaller sizes, connected directly to the tap on the main, without a "goose neck."

Question No. 18. When street grades are changed, is the cost of lowering water mains, hydrant branches, services, etc., borne by the water department or company or by the city?

Mr. C. R. Henderson: If grade is established and afterwards changed, thereby requiring relaying of mains, the cost of relaying is paid by the city of Davenport, Iowa, to the water company.

Mr. Robert Spurr Weston: Charge paid for by the city when ordered by the city; otherwise cost is borne by company.

Secretary: At Paris, Kentucky; Iron Mountain, Michigan; Lake Charles, Louisiana, and Clarksburg, West Virginia, where the water works are owned and operated by private companies, the city pays the cost of changing grades of water pipes. The franchises of the companies provide for this.

At Perth, Ontario; Coalinga, California; Ripon, Wisconsin; Utica, New York; Lincoln, Illinois, and Quincy, Illinois, the companies have to stand the expense of lowering water pipes and other water fixtures when street grades are changed.

At Cincinnati, Ohio; Brantford, Canada; Los Angeles, California; Milwaukee, Wisconsin, and Elyria, Ohio, the cost is borne by the water departments.

Question No. 19. What has been your experience and what legal decisions have you had concerning liability for damages caused by burst water mains?

Mr. A. W. Ellson Fawkes: The city of Calgary, Alberta, accepts liability to avoid law suits if possible.

Mr. H. P. Bohman: The supreme court of Wisconsin has held that negligence on part of the city must be proven; otherwise there is no liability.

Mr. W. L. Cameron: Have paid many claims because law suits are expensive; never allowed a case to come to trial if possible to settle it outside of court.

Mr. William Perry: The owner of the works should be responsible for any such damages.

Mr. R. U. Sherman: At Utica, New York, the policy and practice of the water company is to settle as promptly as possible.

Mr. W. R. Gelston: Have never allowed a case to go to court at Quincy, Illinois.

Mr. J. A. Hiller: In a majority of cases the Cincinnati Water Department has obtained a verdict of no damages. However, in a particular case which was recently decided in the Ohio Supreme Court damages were awarded to a party who suffered damages due to lack of water while a main was shut down for repairs.

Question No. 20: Have you had any experience with damage to hot water boilers by reason of shutting off water?

Mr. A. A. Reimer: If people would shut down their fires as we tell them to, they would not have any trouble. We send a man around as soon as possible in case of a break and warn every person affected by the shutoff or break to kill his fire as quickly as possible, and open up a hot water faucet at the highest point and leave it open a little bit until the trouble is over. If they do that there will be no trouble. In a few cases they have failed to do that, and then there has been trouble; but we are absolutely free from responsibility in those cases.

When water is shut off to repair a main or for other cause the following notice is left at each house affected by the shut off:

IMPORTANT

Water Department City of East Orange

City Hall, Main Street

Telephone 3642 E.O.

East Orange, N. J.,.....

It will be necessary to *Shut Off* water at.....o'clock, ...M., on.....to make necessary repairs or connections. All persons having boilers within their premises are cautioned against drawing water from same while the supply is shut off, and are also warned to keep all boiler fires low until the supply is turned on again.

Such water as will be needed for ordinary uses while supply is shut off, should be drawn *at once*, or well in advance of time for shutting off supply.

Arthur A. Reimer,
Engineer.

MR. CHARLES L. BOWKER: Yes, but owners were all notified to look after their fixtures and it was due to their own neglect that such accidents happened. We have paid no damages at Brunswick, Maine, for such accidents.

MR. H. P. BOHMAN: The Milwaukee Water Department before shutting off water for repairs or for any cause serves each consumer affected with a printed "shut off notice," printed in three languages, in which he is instructed to keep faucets open while supply is shut off. Have had no troubles.

MR. WILLIAM PERRY: Have had copper boilers collapse. Had a vacuum valve been arranged on the boilers it would not have taken place.

MR. W. R. GELSTON: At Quincy, Illinois, we burned out one instantaneous heater while flushing a dead end. The pressure was low and the heater on the second floor got overheated.

A copper boiler which was not properly protected by a check valve collapsed when water was shut off and main drained.

QUESTION NO. 21. What are your rules and regulations governing the extension of water mains?

MR. R. J. SMITH: The Perth (Ontario) Water Company is compelled to extend mains when a revenue equal to 6 per cent on the cost of such extension is guaranteed for the first two years by consumers.

MR. CHARLES L. BOWKER: The Brunswick (Maine) water company extends mains on a 10 per cent guarantee on the actual cost, which includes the hydrant rental paid by the city.

MR. C. R. HENDERSON: Extensions may be ordered by the city council if there are three consumers to each 400 feet. Fire hydrants are placed at the rate of nine to the mile.

MR. NEWTON MITCHELL: The city of Paris, Kentucky, pays for one hydrant for each 500 feet of water main extended.

Mr. F. W. Frank: At Brantford, Canada, we must have an earning capacity of 8 per cent guaranteed on the cost of the extension.

Mr. A. E. Croll: The city of Iron Mountain, Michigan, orders mains laid and we lay them at our expense and are entitled to one fire hydrant for every 500 feet or major part of 500 feet.

Mr. F. C. Amsbary: The franchise of the Champaign (Illinois) water company provides that when council orders water mains extended, the city shall rent one fire hydrant for each 400 feet of such extension. We are not obliged to extend unless in addition to fire hydrants we secure three *bona fide* consumers for each 400 feet extended.

Mr. T. J. Bird: The city of Lake Charles, Louisiana, orders extensions, renting one fire hydrant for each 490 feet extended.

Mr. Emmett MacDonald: At Lincoln, Illinois, mains are extended by order of the council, they allowing fire hydrants at the rate of ten per mile on the extensions.

Mr. Lewis M. Bancroft: At Reading, Massachusetts, we must have a revenue of 4 per cent on the cost of the extension.

Los Angeles, California: A deposit of 50 cents per foot is required to secure the main, and an assessment of 80 cents per front foot must be paid when a service is ordered for a lot.

Mr. Robert Spurr Weston: One hundred feet of extension is made for each new service. In case more than 100 feet is required to supply one service the excess to be paid for by the customer.

Mr. H. P. Bohman: In Milwaukee abutting property is assessed on the basis of the cost of laying a 6 inch main, regardless of the size actually laid. The cost to the property is about 50 cents per linear foot each side of street. Corner lots are given a deduction of one third of the two frontages. Street and alley intersections, feeder mains and excess of cost of laying pipe over 6 inches in diameter is paid out of water fund.

Mr. W. E. Hazelton: At Ripon, Wisconsin, mains are extended only on an order from the city for additional fire hydrants, about 600 feet of main for each hydrant.

Mr. Henry T. Boyden: In allotments mains are laid when the owners will guarantee water rental equaling 10 per cent of cost of main.

Mr. R. U. Sherman: At Utica, New York, there are three methods of getting a main laid where the company has no reason for laying one on its own initiative.

First: By order of the city and placing of hydrants.

Second: By a five year guarantee of land owners of 10 cents per year per linear foot.

Third: By guarantee of the land owners to pay such amounts as will bring the revenue from the extension up to 10 per cent of its cost, so long as such payments are necessary to make the revenue amount to 10 per cent.

Mr. Thos. E. Irwin: This is a question upon which we have had a great deal of discussion in our board and one which we have been unable to settle satisfactorily to all parties concerned. Our practice has been that we should obtain a guarantee from the property owners along the proposed mains equal to ten cents per running foot of pipe for not over six inch mains. This at first was apparently satisfactory and at the expiration of the first year we were not obliged to call on the property owners for any deficit on said extension, but later experience taught us it was very unsatisfactory, as some agreements made upon this basis have never paid for themselves and the company has been out of pocket by considerable. We are now discussing the adoption of a plan requiring the applicant for extension to deposit the cost of said extension for which the company will furnish the applicant for a period not exceeding five years, with water at the regular rates. When the consumption of water equals the amount of the deposit made by the applicant or at the expiration of the 5 years, the contract is closed and the pipe then becomes the property of the company absolutely. After that time the consumer signs an agreement and payments for the consumption of water are made in the regular way. This plan seems to work fairly well as far as we have gone with it and yet we should like to hear of other plans.

Mr. J. A. Hiller: The city of Cincinnati extends water mains when property owners petition for same and guarantee an annual revenue equal to 10 per cent of the cost of the extension.

Mr. W. R. Gelston: We will extend our mains into any territory within the city limits, where it is evident that new business will develop, provided one or more consumers will sign three year contracts guaranteeing to pay us in water rates a sum sufficient to furnish us a fair rate of interest on the investment. What constitutes a fair rate of interest in our opinion, varies with the individual extensions. Where the prospect for new business is very bright, we are satisfied with 6 per cent on the investment. Where it is desirable to make an extension, using a pipe larger than 6 inch, for fire protection, we do not require even 6 per cent. Sometimes we can eliminate one or more dead ends by laying an extension and this is considered worth something to the company and the extension is laid although we would not be justified in laying it if the proposition was decided strictly on the merits of the signed contracts.

Mr. A. A. Reimer: In our city we use an agreement form requiring the owners of property along the new line to deposit the estimated cost of the work. This money is used by the department to lay the main and is not refunded to the owners until the water revenue from improvements along the new main amounts to 10 per cent per year of the amount deposited. When the 10 per cent point is reached, the original amount is refunded to the owners. We also use a modification of this first method by accepting a bond from the owners guaranteeing the payment of 10 per cent per year of the cost of the main, this bond to run until the normal water revenue from the new main equals the 10 per cent. A copy of the agreement form used is offered here, if it is of interest to any of the members.

THE CITY OF EAST ORANGE

WATER DEPARTMENT

AGREEMENT FOR LAYING WATER MAIN

THIS AGREEMENT made and entered into this day of , 191 , between The City of East Orange, a municipal corporation in the County of Essex and State of New Jersey, by the Board of Water Commissioners thereof, party of the First Part, and

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. . . . . .

individually and collectively constituting the part of the Second Part:

WITNESSETH, THAT WHEREAS, the part of the Second Part, the owner of property abutting on Street, between Street and Street, in the city of East Orange and desirous of having a water main laid in said street, and supply pipes laid from said main to the curb line at each individual building lot;

AND WHEREAS, after due investigation the party of the First Part is of the opinion that the revenue likely to be derived from service connections along said street will not for some time be sufficient to warrant the construction of said main;

AND WHEREAS, the part of the Second Part willing to advance the cost of constructing said main under the conditions and terms hereinafter named:

IT IS THEREFORE AGREED, between the parties hereto, as follows, to wit:

1. That the estimated cost of constructing a inch water main on said Street, from the line of Street to the line of Street, with the necessary connection to the present street main on Street and Street, including valves, bends, and special castings and other necessary parts, but exclusive of fire hydrants and connections to the same, and exclusive of supply pipes from the main to the curb line, is the sum of Dollars, ($).

2. That in consideration of the construction of said main the part of the Second Part agree to pay, and ha paid to the Collector of Taxes of the said The City of East Orange, for "The advanced Pipe Construction Account" of the Water Department Fund of said city the said sum of Dollars, ($), above named as the estimated cost of said main, and ha presented to the party of the First Part the receipt of said Collector of Taxes for the same, which said sum is to be used by the Water Department for the construction of said main.

The amount contributed by each of the parties of the Second Part to make up the said sum of Dollars, ($), and the property owned on said street by each, are as follows:

NAME	DESCRIPTION OF PROPERTY	AMOUNT PAID

3. Upon the payment to the Collector of Taxes of the said sum of Dollars, ($), evidenced by the receipt from said Collector of Taxes, and the execution of this agreement by all the parties hereto, the party of the First Part agrees to supply all the necessary pipe and other materials and specials required and to construct said main and to connect it with the water supply of the city of East Orange and to put in supply pipes from said main to the street curb opposite each building lot or site, as soon as practicable.

4. Whenever the revenue received on account of water supplied through said main between Street and Street, shall, for each of two successive revenue quarters of the year, be equal to or exceed the sum of Dollars, ($), per quarter, the party of the First Part shall refund to the part of the Second Part or to agents, attorneys, assigns, executors, administrators or heirs, the whole of the sum of Dollars, ($), advanced by said part of the Second Part for the construction of the said main; but no interest shall be allowed or paid to said part of the Second Part or any of them upon said sum or any part thereof for the period during which it shall have been in the custody of the party of the First Part, or the Collector of Taxes or the City Treasurer of the City of East Orange.

The repayment of said sum shall be made to the individual who originally contributed said sum of Dollars, ($), or to agents, attorneys, assigns, executors or heirs, as set out in Section 2 of this agreement, on warrants signed by the President of the Board of Water Commissioners and the Mayor of The City of East Orange, each individual to be paid the amount contributed by him.

In case the revenue received by The City of East Orange for water supplied through said main to property belonging, at the time this agreement is executed, to any one of the individuals named as contributors to the said fund of Dollars, ($), as set out in Section 2 of this agreement, shall for two successive revenue quarters of the year equal or exceed the rate of five per centum per annum on the sum contributed by the said individual contributor, then the party of the First Part shall refund, without interest, to said individual contributor, or to his agents, attorneys, assigns, executors, administrators or heirs, the sum originally paid by him, on warrant signed as afore-

said, without waiting until the other property along the street, as a whole, shall yield the requisite revenue to release the whole of said fund of Dollars, ($).

5. Supply pipes from the said main to the street curb line shall be put in by the party of the First Part opposite each separate lot or building site on said street at the time the main is laid; the work to be done and the fee paid therefor to be in accordance with the provisions of the ordinance adopted by the Board of Water Commissioners of The City of East Orange on the 15th day of March, 1910 (in effect March 25, 1910), or such supplements or amendments thereto as may be hereafter made.

In witness whereof the party of the First Part has caused the President of the Board of Water Commissioners of the said The City of East Orange to sign this agreement on its behalf and the part of the Second Part ha each attached name and seal on this the day of A. D., 191 .

The City of East Orange,
By The Board of Water Commissioners,

(*Seal.*)

By .....
President.

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Mayor.

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Secretary, Board of Water Commissioners.

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Question No. 22. Are fire alarms answered by your department? If so, what provisions are made for this?

Mr. C. R. Henderson: Yes; strikers in each pumping station and at office. Answered from office in office hours, at other times by telephone call from pumping station to residence of proper person.

Mr. Newton Mitchell: Yes; have fire alarm service in office.

Mr. Emmett MacDonald: Yes, our men are notified of all fires by telephone.

Mr. Robert Spurr Weston: A water works man answers all fire alarms.

Mr. H. P. Bohman: Second or general alarms are answered. Two watchmen on duty every night to answer calls of this nature.

Mr. W. E. Hazelton: At Ripon, Wisconsin, we have fire alarms in station, office and some employees' houses; also a fire whistle for signaling. Each alarm is recorded on gage at office.

Mr. W. F. Wilcox: The Mississippi Supreme Court has decided that it is not necessary for a superintendent of water works to be present or to have a representative at every fire alarm; but that in case of any fire being of such magnitude that it would become common knowledge, then it would be the duty of the superintendent to have knowledge of the fire and know that the operation of the water works was efficient and prompt.

Mr. W. S. Cramer: At Lexington, Kentucky, the water works answers fire alarms. We have an automobile truck, used by the pipe foreman in his work, and on second alarms some one from the water works department responds, the truck being always in readiness, especially at night.

On private fire services we put an indicator post valve at the curb line and the mutual understanding between the fire chief and the company is that, when the chief gets on the ground, the first thing he does is shut off the sprinkler connection. Our indicator post valves have an operating stem nut corresponding to our fire hydrant operating nuts and open and close in the same direction.

Question No. 23. Do you test water mains under pressure after they are laid and before the trench is filled?

Mr. C. R. Knowles: Always test mains before trench is filled if possible, and if extensive system of mains after the system is connected up with it.

Mr. C. B. Chessington: It depends on the time of year work is done, amount and character of soil. Where practicable test should be made.

Mr. H. P. Bohman: At Milwaukee we test river crossings only. All pipe is tested at the foundry and constantly inspected by city inspector while being laid in trench.

Mr. W. L. Cameron: The pipe will be more apt to blow out if the trench is not filled. The pipe should be well tested and carefully put together.

Mr. William Perry: Always put a pressure of from 150 to 200 pounds on lengths of from 500 to 1000 feet.

Secretary: Of the cities answering this question the following named do test pipes in trench before backfilling: Perth, Ontario; Calgary, Alberta; Paris, Kentucky; Brantford, Canada; Iron Mountain, Michigan; Champaign, Illinois; Lake Charles, Louisiana; Los Angeles, California; Ripon, Wisconsin; Huntington, New York; Quincy, Illinois, and East Orange, New Jersey.

The following named from those who responded do not make such a test: Brunswick, Maine; Davenport, Iowa; Lincoln, Illinois, and Reading, Massachusetts.

Question No. 24. If pressure tests are made of pipes in the trench how are such tests made and on what length of pipe is the test usually made?

Mr. W. E. Hazelton: At Ripon, Wisconsin, we use a regular cast iron pipe plug with a $\frac{1}{2}$ inch round "Rainbow" manhole gasket and a handmade yoke going over pipe back of bell. Usually test about one block.

Mr. T. J. Bird: The water is turned on a section of pipe before the trench is filled at Lake Charles, Louisiana.

Mr. F. C. Amsbary: We test with a patent plug clamp which fits in bell of pipe.

Mr. A. E. Croll: At Iron Mountain, Michigan, we test the full length of pipe line before filling trench.

Mr. F. W. Frank: We test about every hundred feet at Brantford, Canada, using a temporary plug.

Mr. Newton Mitchell: At Paris, Kentucky, we test 500 foot lengths of pipe line.

Mr. R. L. Peeler: At Coalinga, California, we test such lengths of pipe line as the congestion on the streets will permit, usually short distances. We put a plug in the line and turn on the pressure pump.

Mr. R. J. Smith: Tests are made at Perth, Ontario, by plugging each 100 feet of pipe and putting on 125 pounds pressure.

Mr. J. B. Chessington: At Thermopolis, Wyoming, we test by shutting valve on end of new line and turning in water slowly, releasing air through a hydrant or service cock. The length tested depends on the distance between valves.

Mr. Henry T. Boyden: At Elyria, Ohio, we test mains using a test plug, if no valve is available in the main. We test any length that we happen to have, and intend to test every joint under pressure before backfilling.

Mr. W. R. Gelston: At Quincy, Illinois, we test by using a test plug and the ordinary city pressure at the locality.

Mr. C. R. Knowles: Usually use temporary pump direct on main to be tested, using recording gage and maintaining pressure above maximum working conditions for sufficient length of time to insure a safe line.

Mr. Thos. E. Irwin: At Huntington, New York, it is our usual custom to work from gate to gate, never over 1000 feet; often we will test out 400 or 500 feet.

Question No. 25. Have you found test plugs reliable and satisfactory for testing pipe under pressure?

Mr. W. E. Hazelton: Have found the device described in answer to the preceding question very satisfactory.

Mr. A. E. Croll: We use a wooden plug and find it reliable and satisfactory.

Mr. F. W. Frank: Have found test plugs very staisfactory.

Mr. R. J. Smith: Yes, have found test plugs all right.

Mr. Henry T. Boyden: Have found them satisfactory with the pressure we have at Elyria, Ohio, 50 to 60 pounds.

Mr. W. R. Gelston: Test plugs have been satisfactory.

Mr. E. E. Davis: We encountered a peculiar condition in laying a 20 inch pipe at the bottom of the James river down in the rock. The contractor had some trouble with a specially made testing plug. So we took an ordinary cast iron plug and bored a hole in it near the top, for pumping up the pressure and that was the best plug we ever had. When the test was finished the lead was melted out and the same plug used on the next test.

Mr. W. W. De Berard: Some experience from Detroit might be interesting. Testing the pipe in the trench for water tightness is carried out before backfilling on sections 200 to 1000 feet long. For 6, 8, 10 and 12-inch pipe testing boxes similar to the body of an ordinary gate valve are used instead of plugs where it is not convenient or necessary to insert valves. The seats are faced in cast iron and not lined with brass. When a test is to be made, the box is inserted in the line, where it is converted into a gate valve by means of an ordinary bonnet, disk and stem. In the meantime pipe laying may proceed beyond the box. On completion of the test no water need be pumped from the trench. After a section has been tested, and the water turned on, opening the test box permits filling the next section. When the tests on sections of pipe on each side of a box are completed, the valve parts are removed and the bonnet replaced by a blank flange. The 6, 8, 10 and 12-inch boxes cost $5.10, $8.47, $10.40 and $14.23, respectively.

Question No. 26. Do you consider the supplying of water for power purposes—motors, elevators, etc.—a legitimate or proper function for a water department or company?

Mr. Robert Spurr Weston: Yes, if mains are of sufficient size to allow it.

Mr. T. J. Bird: Yes, if it is profitable business. The company is in business to sell water at a profit. Of course, the supply must be adequate.

Mr. F. C. Amsbary: No, although we have at Champaign, Illinois, over 200 washing machines run by water motors. All are on meters and we consider them profitable.

Mr. C. R. Henderson: No, not with fire pressure service as at Davenport, Iowa; and do not favor it under usual and ordinary conditions.

Mr. L. M. Bowker: No, unless such service is metered and a meter rate large enough to give a fair return.

Mr. J. A. Hiller: In Cincinnati we do not consider it a proper function of the water department to furnish power. Generally the furnishing of power necessitates the carrying of increased pressure, greater pumping expense, heavier mains and services. It is only the occasional consumer who wishes power; all consumers must pay the cost of the additoinal pumping, etc.

Mr. W. R. Gelston: Yes, if a consumer is willing to pay for water for such purposes and use it under such restrictions as may be necessary for the protection of the department and the general public. The business should be desirable.

Mr. C. R. Knowles: Would consider the supplying of water for power purposes, within certain limits, a legitimate and proper function of a water department or company, as in many cases it might be the most adaptable power to use.

Mr. W. F. Wilcox: It is only feasible for water companies to furnish water for power purposes in localities where the pressure is

abnormal. Where the water has only the ordinary pressure electric power is cheaper. A city where they can use the hydraulic power to good effect is Vicksburg, Mississippi, where it is very hilly. The stand pipe gives a minimum of 17 pounds on the higher elevations and 140 on the levee. The factories are mostly on the levee and the 140 pounds pressure makes it feasible to furnish hydraulic power. As a general rule, unless there is some local condition making the pressure in certain parts of the town abnormal it is not practicable for a water company to undertake to furnish power.

Figure out the horse power at 140 pounds pressure and water at 15 cents per 1000 gallons and you will find that it makes very cheap power.

QUESTION No. 27. If water is supplied for power purposes, should special rates be made for such service?

MR. DOW R. GWINN: No, sir, unless they are made specially high.

MR. T. J. BIRD: A rate should be made which will get the business and yield a profit including *all* costs.

MR. F. C. AMSBARY: It depends on the supply, if you have abundant supply and capacity special rates might be justifiable.

QUESTION No. 28. Have you had any experience with Kellogg or other makes or patterns of "quick repair sleeves?" If so, have they proved satisfactory?

MR. E. E. DAVIS: Have used but one Kellogg sleeve; nothing happened to it. Generally use a common split sleeve which is long enough.

PRESIDENT GWINN: When we have had trouble with joints leaking under a railroad we put on extra heavy sleeves right over the bell and have no further trouble with them.

MR. EARL W. KELLY: Do you use lead wool in those sleeves?

PRESIDENT GWINN: We work in the lead wool to get a solid and substantial joint in the original pipe line, then put this sleeve on the outside.

Mr. Earl W. Kelly: What packing do you use in the sleeve joint?

President Gwinn: Just ordinary sheet lead; rubber might wear out. Am not sure but what they are made with ground joints.

Mr. J. M. Diven: There is little or no danger of rubber packing giving out, no more danger than there would be in a valve. Why would not the same packing that we use in a valve apply to a sleeve?

Mr. E. H. Breidenbach: The trouble is that you burn the packing when pouring the joint.

Mr. A. A. Reimer: Use asbestos packing and you will get away from that trouble. Use good asbestos paper.

Mr. Earl W. Kelly: We have had difficulty in getting them packed; it seems that in caulking the end joints it will spring enough to leak.

Mr. A. A. Reimer: Every time, sure.

Mr. J. M. Diven: The use of lead wool for the lead joints will prevent the trouble from burning the packing or gasket in making joints.

As to the leaks caused by springing when joint is caulked, this can be prevented by tightening up the bolts near the ends of the sleeves after they are caulked. Do not caulk too hard before doing this, tightening the bolts will help pack the lead joint.

Have used the sleeves with rubber gaskets and never had any trouble from leaks or giving out of the gasket. Any leaks that showed when the water was turned on were stopped by tightening the bolts.

Mr. Emmett MacDonald: Yes, we use them at Lincoln, Illinois, and find them a good thing. We think that they should be always kept on hand for emergencies.

Mr. F. C. Amsbary: No, in case of split pipes we put on clamps and have always found them satisfactory and to give good results.

Mr. Charles L. Bowker: Yes, they are an admirable makeshift, but should be used as a last resort.

Mr. R. L. Peeler: We have not used the Kellogg or similar sleeves at Coalinga, but have used Dresser joints for leaky joints.

Mr. C. R. Knowles: Have used "quick repair sleeves" in close places with indifferent success; would advocate their use only in exceptional cases.

Question No. 29. Do you use pressure recording gages? If so, what benefits do you derive from them?

Mr. A. A. Reimer: The speaker has one in his house, for his own comfort. The last thing before going to bed is to look at that gage, and then retire with a quiet conscience and peaceful heart.

Mr. John M. Diven: There is an additional value besides your own comfort. The recording gage charts settle the question as to what your pressure was at any hour, night or day. They settle all disputes concerning pressures, and have been known to stave off law suits.

Mr. A. A. Reimer: They are of inestimable value as court records if for nothing else. Take a case of claim of low pressure at the time of a fire and if you have your charts you can show the exact condition at the time. If full pressure is shown there must have been something the matter with the hose line or engine or local trouble of some kind. There is no better way of proving it, and you may win your case with the one little chart.

Mr. J. Walter Ackerman: Nobody has a stronger realization of that than the present speaker. He sat for three warm days in July in the witness-box and never budged from the pressure chart; he stood three days of hammering but went through on that proposition.

Mr. W. F. Wilcox: Recording pressure gages are now regarded by nearly everyone as an absolute necessity. Much valuable information can be obtained by water works superintendents by putting recording gages at various points on the water system. Larger corporations require recording gages on many different

kinds of apparatus, the more important being conduits for water, gas, steam and electricity.

Boiler plants should have them both on the steam and feed water heaters.

A good type of recording gage can be purchased for $50 and almost any plant, no matter how small, can save this cost several times the first year.

Mr. Scotland G. Highland: We consider pressure recording gages indispensable. They furnish continuous and indisputable information, and compel safe, intelligent and efficient operation.

Mr. W. E. Hazeltine: We would not think of being without them. They have settled many disputes with the city, especially as to fire pressures. We have our office gage supplied with an extra hand connected with the fire alarm system which records time that alarms are turned in.

Mr. Robert Spurr Weston: Yes, they make record of pumping, record of time during which high pressure (fire pressure) was on and pressure maintained during fires.

Mr. L. M. Bancroft: We have a recording gage in the office. Have never received any benefit from it, except the satisfaction of knowing where the water pressure is at all times.

Secretary: Los Angeles, California, reports use of pressure recording gages to find the requirements in localities where complaint is made of poor supply.

Mr. Emmett MacDonald: Occasionally the firemen lay a very long string of hose and then complain about poor pressure. The gages protect us, and we would not be without them.

Mr. T. J. Bird: We find them very reliable at Lake Charles, Louisiana, in case of any complaint of low pressure, especially during fires.

Mr. F. C. Amsbary: At Champaign we have these gages at pumping house, office and fire department; do not see how we could get along without them.

Mr. A. E. Croll: At Iron Mountain we maintain them solely for showing pressures at fires.

Mr. Newton Mitchell: Yes, find that they keep a record on the night engineers.

Mr. C. R. Henderson: Yes; they are indispensable and give to proper authority a continuous history of the service rendered in regard to pressure.

Mr. A. W. Ellson Fawkes: Yes; we find the records useful for reference to district pressures.

Mr. R. L. Peeler: We use recording gages at Coalinga, California; the only benefit we derive from them is the satisfaction of knowing what we are doing.

Mr. H. P. Bohman: They give a record of the pressure maintained during the entire twenty-four hours of each day. Complaints of lack of pressure in case of fires are easily checked up for refutation.

Mr. W. L. Cameron: In a lawsuit between Kansas City, Missouri, and the National Water Works Company these gages proved that there was sufficient pressure at a certain fire when the city claimed otherwise.

Mr. R. O. Wynne-Roberts: Pressure recording gages are certainly useful, as by such means the fluctuations in pressure are automatically recorded; the engineer is able to judge the results of increased consumption and where large mains are necessary. Have always had a number of such gages installed.

Mr. R. U. Sherman: Yes. In case of bad fires we have absolutely positive proof as to the general pressure conditions. This is particularly valuable where the fire has been large and a part of the blame is very apt to be placed upon the water system. The pressure gage notifies us at once of any serious break, and is valuable in connection with the fluctuations in draft.

Mr. Henry T. Boyden: Yes. Our pumping station is ten miles away; we pump to the mains direct without stand pipe or reservoir so that a pressure recording gauge is a necessity as a check against the pumping station; also consider them a necessity as a matter of record.

Mr. J. A. Hiller: We have a few recording gauges at Cincinnati. These have proven valuable in some cases in fixing the time of large breaks in mains.

Mr. W. R. Gelston: Yes, we consider it very desirable to have a record of water and steam pressures on file.

Mr. C. R. Knowles: We use recording gauges on steam and water lines at fire protection plants as a means of keeping a check on pressures maintained at all hours.

Mr. Thos. E. Irwin: We certainly do use recording gauges at Huntington, New York, as follows: One steam pressure gauge with charts which are changed every day and returned to the office, and the benefit derived from this shows whether the engineer is looking after his end of the plant and keeping steam where it is required for the work to be done. Pressure gauges on the mains are also serviceable affairs, showing at all times what pressure we maintain when pumping or not pumping. In case of a fire and if, for any reason, a question arose as to the pressure carried we have an absolute record of same.

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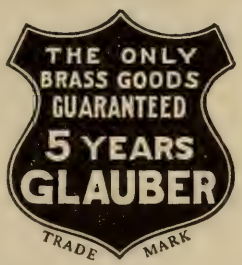

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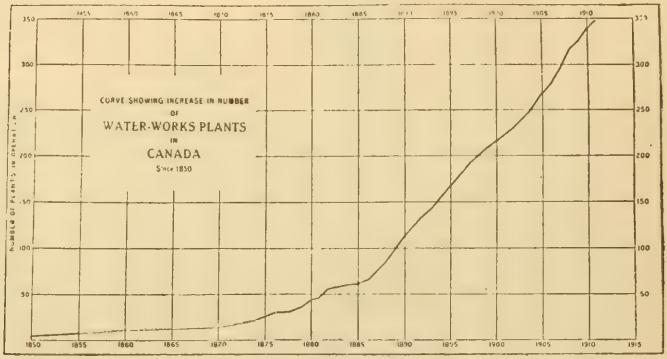

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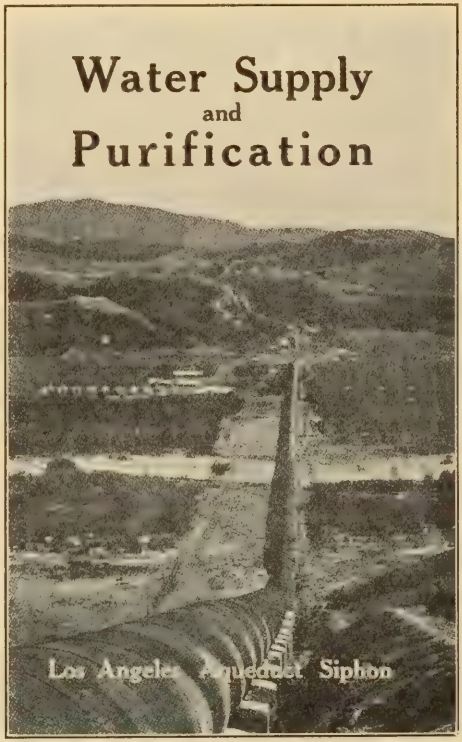

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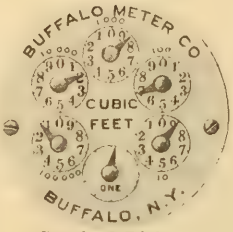

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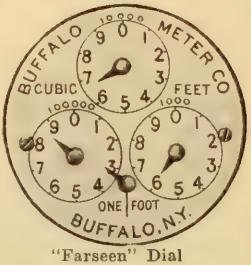

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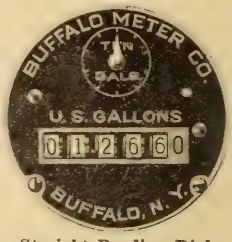

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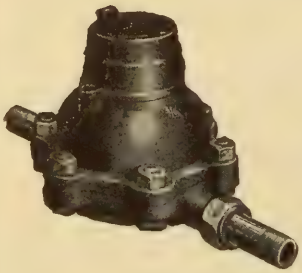

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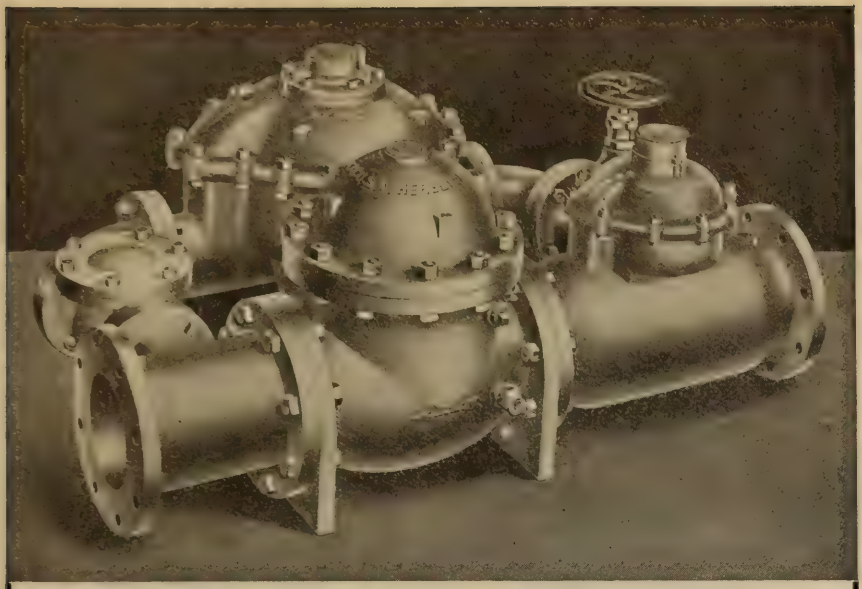

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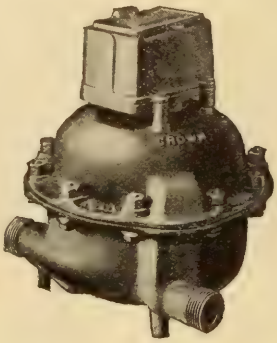

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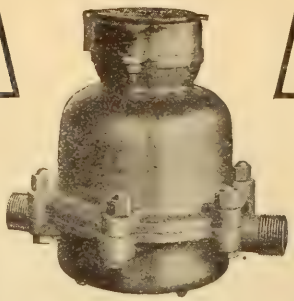

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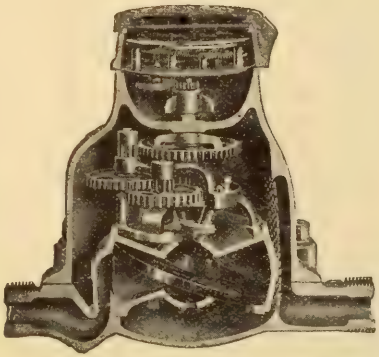

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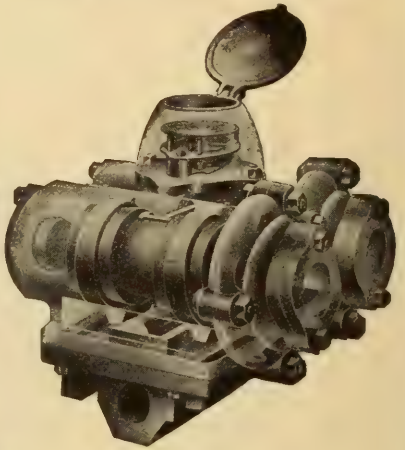

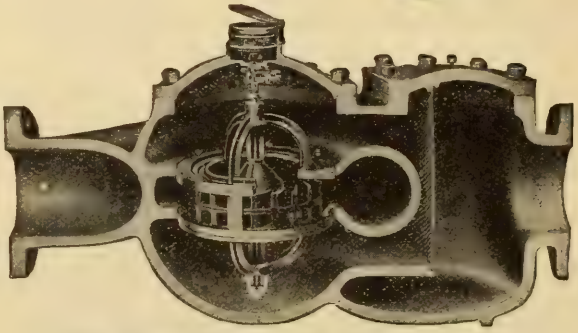

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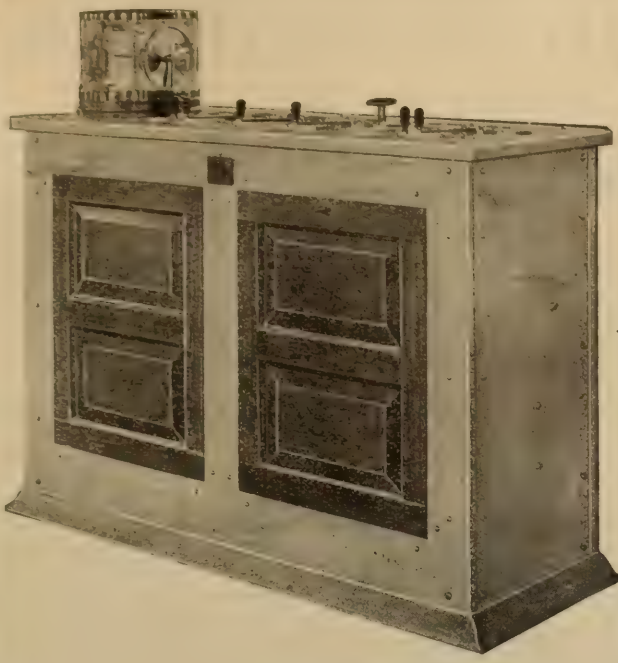

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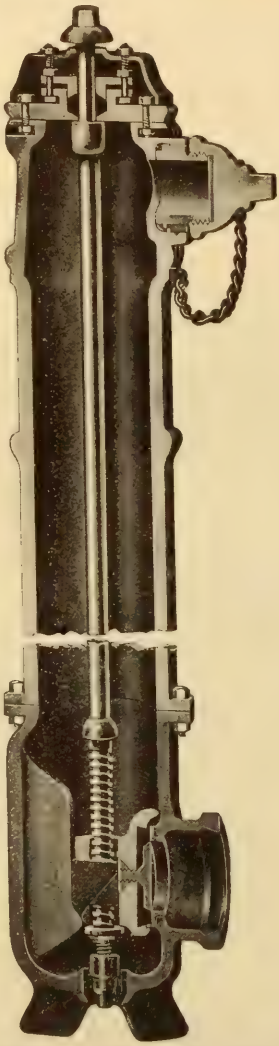

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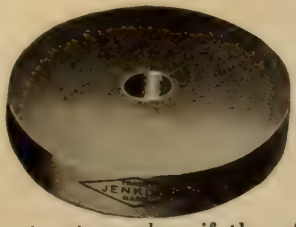

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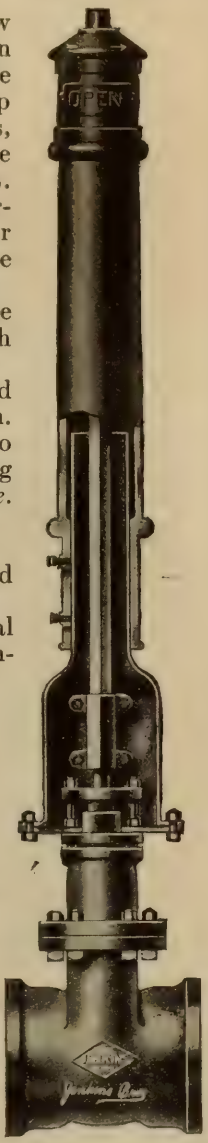

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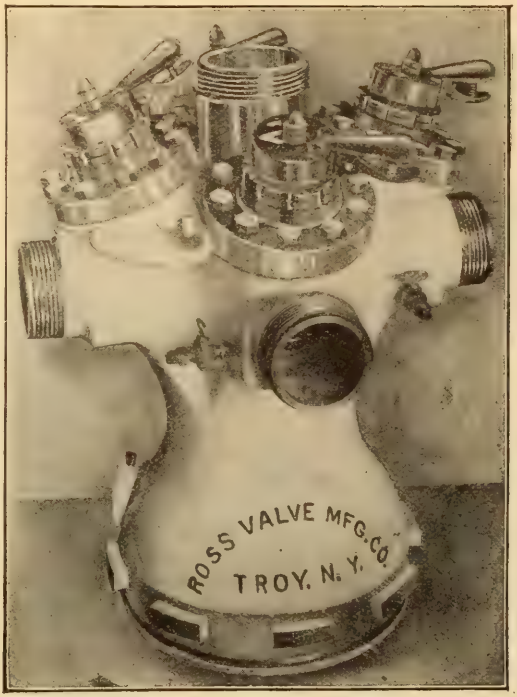

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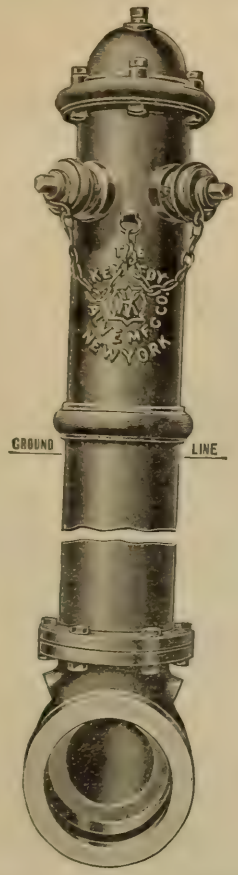

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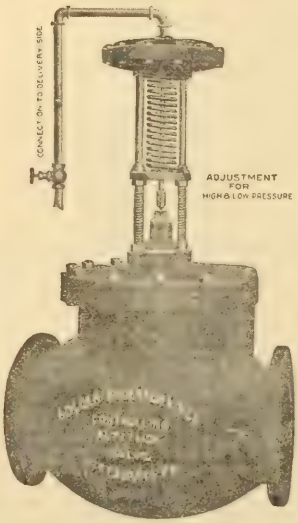

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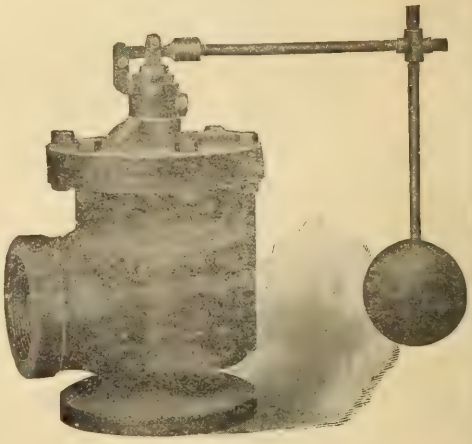

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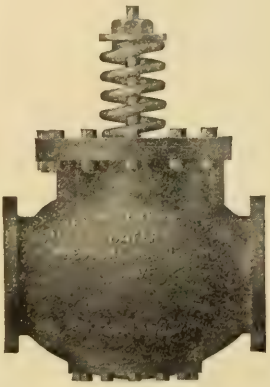

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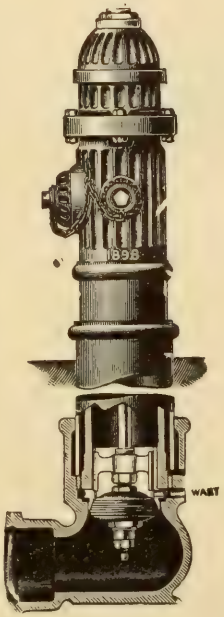

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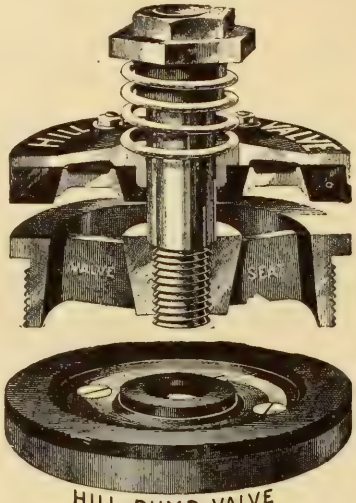

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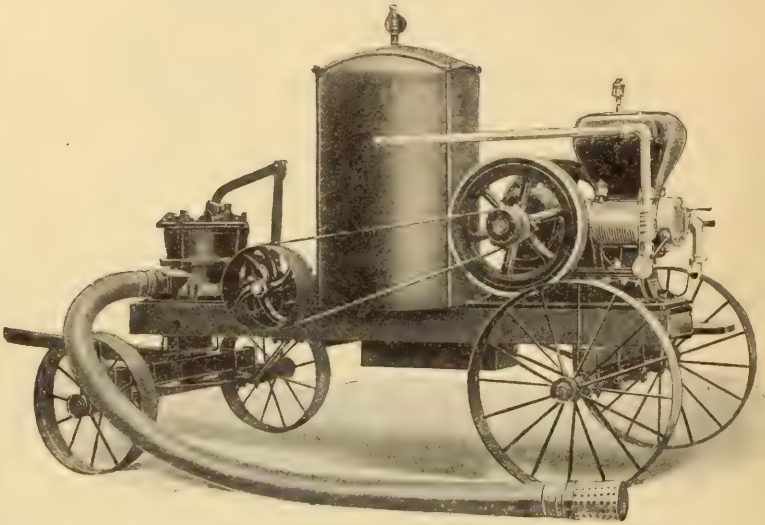
For Calking Lead Joints in Water or Gas Pipes, also for Pumping Water from Trenches and Testing out Gas Pipes by Air Pressure



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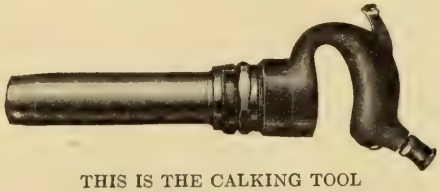

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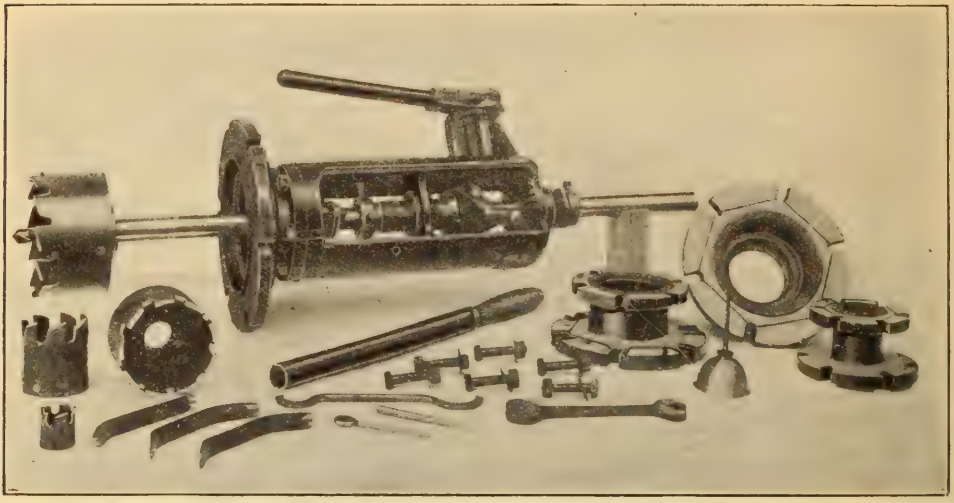
Manufacturers of Tapping Machines, Hydrants, Valves and General Waterworks Supplies.



The above cut shows the Improved Tapping Apparatus; instead of being operated on the end of shaft, necessitating a wide cut in trench for operation, the above machine is shown with gearing mechanism so that the operation is made lengthwise with the machine, thus cutting down the cost of excavation—an important point where expensive pavements have to be disturbed to make important connections. Aside from this, on account of the gearing, the feed of the machine is steady, thereby insuring long life to the cutters and no danger of accident to them while the cut is being made.

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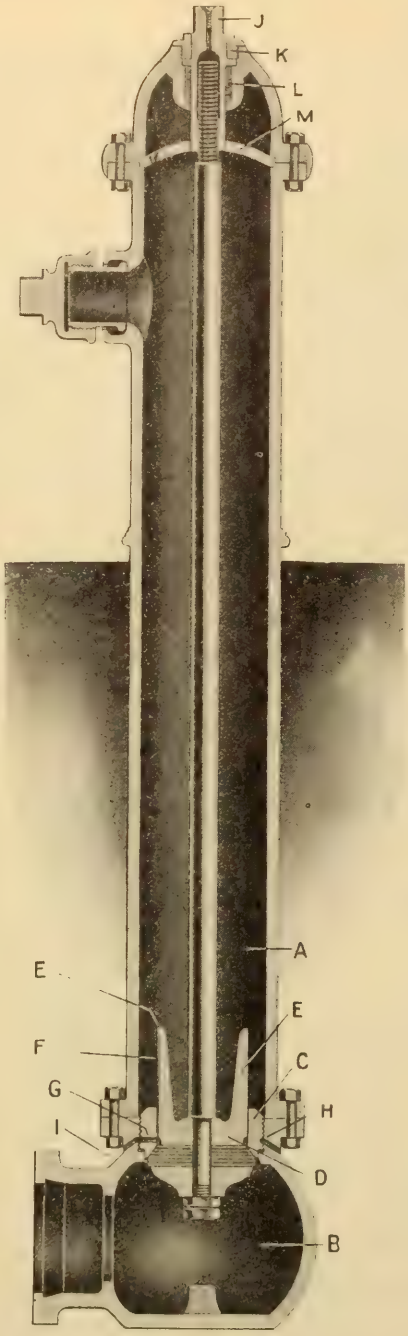

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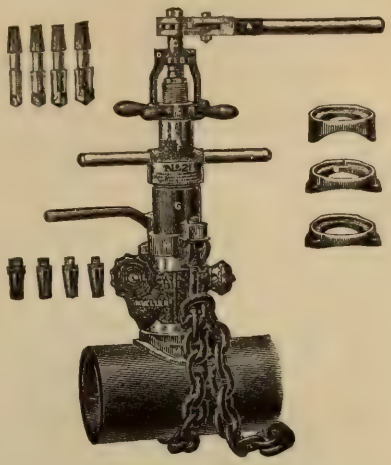

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